I. INTRODUCTION

1. In the Committee's original report (published on 24th March, 1964) five pesticides namely aldrin, dieldrin, heptachlor, DDT and BHC were considered in detail and recommendations made on the extent of their future use. Mention was made of a further five chemicals, endrin, endosulfan, chlordane, "Toxaphene" and "Rhothane" but these were not considered in detail at the time, although information on their use was contained in Appendix E. None of this latter group is used in Great Britain on an extensive scale.

II. THEIR USES IN AGRICULTURE, HORTICULTURE AND HOME GARDENS, IN FOOD STORAGE PRACTICE, INDUSTRIAL PREMISES AND THE HOME, AND IN VETERINARY PRACTICE

2. As stated in the original report all five of the pesticides considered here are available for commercial use in agriculture and horticulture. Chlordane and toxaphene only are available to the home gardener and only endrin and chlordane in food storage practice. None is used in veterinary practice in Great Britain.

Endrin

3. Although endrin is effective against a wide range of pests, it is particularly valuable for the control of certain groups of mites. The most important of these is the blackcurrant gall mite, which transmits the virus causing "reversion" in blackcurrant.

4. Recommendations have been issued for the safe use of endrin on apple, pear, cherry, blackcurrant and non-edible crops. In practice, by far the greatest use is on blackcurrant; it may be used without restriction on propagating stock and non-fruiting bushes but only at the pre-blossom stage on fruiting bushes. An additional post-blossom application would give greater protection but this is not a recommended use as it could lead to unacceptably high endrin residues on the ripe fruit. It is understood that this restriction has been reinforced by the policy of a major blackcurrant juice processing firm, which takes a fair proportion of the annual crop and does not allow the use of endrin by growers under contract.

5. Other uses of endrin in horticulture appear to be limited to a very small scale on apple, on strawberry plants after all the fruit has been picked, on blackberry canes pre-blossom and on narcissus grown under glass. It does not appear to be used on pear and cherry.

6. Lacquers (resins) containing endrin have been used by servicing companies for the protection of stored products in flour mills and other premises, and

official recommendations for safe use were issued in January, 1962. We understand that endrin is no longer used in this way. We also understand that on occasions in the past endrin has been used in thermal vaporizers and tried out on a limited scale in a mouse tracking dust.

7. Endrin has been used fairly extensively abroad for the control of voles in forestry and agriculture. Whilst this use has been effective we understand that opinion was divided on the risk such uses posed to wild life, so that in some countries (e.g. West Germany, Denmark and Czechoslovakia) endrin may be used for vole control without restriction whereas in others (e.g. Belgium, the U.S.S.R., and the Netherlands) its use is not permitted for this purpose.

8. In Great Britain, only limited experiments have been made with endrin for vole control, and these have been confined to fruit orchards and forest plantations. Vole populations fluctuate widely from one year to another and many years may pass before a population reaches a harmful density. When this occurs, damage in orchards and plantations may be very heavy and there is a need for effective control measures.

Endosulfan

9. The official recommendations published in October, 1963, cover its use on blackcurrant, on strawberry plants after all the fruit has been picked and on non-edible crops.

10. Endosulfan has general insecticidal properties but is particularly useful in controlling the same range of mites, including the blackcurrant gall mite, as endrin.

11. Unlike endrin, endosulfan may be applied to fruiting blackcurrant bushes post-blossom, that is, up to three weeks after the first blossom opens. Surveys in 1961–62 in the Eastern counties showed that 80 per cent of the blackcurrant crop was sprayed once with endosulfan against gall mite, and 60 per cent was sprayed twice. In the West Midlands 80 per cent of the crop was treated with endosulfan in 1963. It is estimated that 80 per cent of the total blackcurrant crop, that is about 12,300 acres, is treated with endosulfan annually.

12. Its use to control mites on strawberry plants after all the fruit has been picked is not extensive at present. It has a very small use for the control of bulb scale mite on narcissus grown under glass.

Chlordane

13. This chemical has been used for many years in Great Britain, on a relatively small scale, for the control of cockroaches and tropical ants e.g. in the kitchens of hospitals, institutions, and the home. It has also been used outdoors for controlling ants around buildings and in gardens.

14. Official clearance was given in 1962 for the use of chlordane to control earth-worms in turf, including lawns. This was without prejudice to any recommendations which might be issued following a future review of the use of the chemical as a whole. Safety precautions for use on the label were, however, sent to all known manufacturers. A number of firms market the chemical for this use both professionally and by the home gardener. Whilst no direct evidence has been provided on how chlordane achieves this

control, it appears that, following the use of chlordane, neither dead worms nor worm-casts are found on turf for a considerable time.

" Toxaphene "

15. " Toxaphene " has been introduced only recently into Great Britain for the control of earth-worms in turf including lawns. Clearance for this use was given in 1962. This was without prejudice to any recommendations which might be issued following a future review of the use of the chemical as a whole. We understand that its use is on a very small scale.

"Rhothane "

16. " Rhothane " (DDD or TDE), which is chemically similar to DDT, is particularly effective for the control of tortricid caterpillars on fruit trees. However, it is probably used on no more than 20 per cent of the orchards in the main fruit growing areas of Eastern and South Eastern England. No official recommendations under the Pesticides Safety Precautions Scheme have so far been made. This chemical has been in use for many years before the introduction of the Scheme and until this review we have not thought it necessary to give its examination priority.

III. THE HAZARDS TO MAN

17. These compounds have been shown to be stored in the fat of experimental animals. There is comparatively little evidence of their storage in the fat of man. Endrin has not been detected in human blood or fat from the general population even in the U.S.A. where endrin is used on a larger scale than in Great Britain. There is some evidence that very small residues of " Rhothane " not exceeding 0·01 parts per million may occur in human milk, but the levels have been so low that it has not so far been possible to confirm them. If present, it is possible that " Rhothane " residues could derive from the use of either DDT or of " Rhothane " as such (see Appendix C to the original report).

18. The acute and chronic toxicities of all the compounds have been studied in conventional tests on experimental animals. Acute functional derangements of the nervous system result but no permanent neurological lesions have been produced. All the compounds may affect the liver cells in the same way as DDT or dieldrin (see page 15 of the original report).

19. A comparison of the single oral dose LD50 (i.e. lethal to 50 per cent of the animals) for rats shows that endrin is somewhat more toxic than dieldrin, while chlordane and " Toxaphene " are appreciably less so.

20. Endosulfan has a relatively high acute toxicity, hence its inclusion in the Agriculture (Poisonous Substances) Regulations in order to protect operators. However, its chronic toxicity is relatively low, presumably because of its rapid metabolism into innocuous substances.

21. " Rhothane " is much less toxic than DDT and is metabolized more rapidly. The op'-isomer of DDD, which forms about 10 per cent of the technical DDD (" Rhothane ") has an inhibitory effect on the function of the adrenal cortex. This effect is most marked in the dog where it

leads to an atrophy of the adrenal cortex. This isomer can also depress adrenal cortical function in man and has been used therapeutically for this purpose, although man does not appear to be very sensitive to it.

22. The chronic toxicities of endrin, chlordane and "Toxaphene", when fed to rats over long periods, vary in a way which probably reflects differences in the rates at which the individual chemicals are metabolised and stored in the fat. In any event their chronic toxicities are not such as to cause any anxiety whatever having regard to the present scale of use of these chemicals.

23. In the conventional two year studies on rats and one year studies on dogs, none of the compounds has given any evidence of a carcinogenic action to either species.

IV. THE HAZARDS TO WILD LIFE

Introduction

24. In our original report we stated that experience with some pesticides has revealed information which, by its very nature, could hardly have come to hand until there had been wide use. The five pesticides reviewed here have, for the most part, been introduced more recently and used on a much smaller scale than those reviewed in our original report. Thus it is difficult for us to assess the risk to wild life from the limited field observations available at present, or even to use such observations to compare any risks from these pesticides with risks from those already reviewed.

Endrin

25. Because the effects of endrin poisoning in birds are rapid, it should not normally be difficult to establish a connection between casualties and the specific use of this pesticide. Nevertheless, although endrin has been used on blackcurrant bushes in Great Britain for over five years, reports of deaths of wild birds or animals, attributable to this use, have been few.

26. In one or two of the reported incidents, the chemical has been or may have been used improperly, for example, as a spray on fruit trees in early spring to deter or control bud-eating birds such as bullfinches. Enquiries following reported incidents have shown, however, that it is usually difficult to establish that such misuses have occurred.

27. The few field trials conducted in Great Britain for the control of voles by means of endrin included fairly intensive biological surveys. These did not indicate that this use resulted in any significant mortality amongst bird populations.

28. As endrin is highly toxic to fish and is a fairly persistent chemical, it clearly represents a potential hazard in waterways. We have received no reports of it having found its way into streams or waterways in Great Britain but we are aware of the alleged poisoning by endrin of large numbers of fish in the lower Mississippi River and the coastal areas of the Gulf of Mexico.

29. The methods of chemical analysis now available for detecting organochlorine residues in biological materials are able to show the presence of endrin even if there in very small amounts (but there are circumstances when its presence can be masked, for example, by relatively large amounts of some other organochlorine residues). Nevertheless, in Great Britain it has rarely been found in tissues examined from birds or other animals. This may be due to its limited use in this country, to its elimination from the animal body more rapidly than dieldrin, or to a combination of these factors.

Endosulfan

30. Endosulfan is one of the pesticides most toxic to fish. It is also toxic to livestock and in Germany and Denmark deaths have occurred among cattle grazing in fields recently treated with the chemical (a practice not followed in this country). Although it has been used on the majority of blackcurrant plantations in Great Britain since 1961, it is not known to have caused any wild life deaths.

Chlordane

31. In the early days of its use abroad, when it contained certain highly toxic impurities now no longer present in the product, chlordane was reported to have caused bird deaths following the spraying of grassland. Reports from abroad also recorded deaths of wild life following the use of mixed chlordane-" Toxaphene " bran baits for grasshopper control.

32. The use of chlordane in this country for the control of cockroaches and ants, indoors and outside, offers no obvious risks to wild life. On the other hand, its use for the control of earth-worms suggests a potential hazard to birds and domestic animals. Chlordane is a persistent chemical and is stored in fatty tissues. It is possible, therefore, that earth-worms and other soil fauna may accumulate chlordane in their bodies and so ultimately present a " food chain " risk.

33. Recent experimental work and current field observations in Great Britain have not confirmed this risk so far. Chlordane has been found in only one or two of the numerous bird bodies analysed during the past two or three years. This latter finding, however, may be explained by the small scale on which the chemical is used.

" Toxaphene "

34. This chemical is also very toxic to fish and has caused casualties amongst fish and other wild life when used abroad for purposes not current in Great Britain. There is no evidence so far of wild life having been affected from its use here.

" Rhothane "

35. Although no direct evidence has come to light of " Rhothane " having caused deaths amongst wild life in Great Britain, residues of this chemical have been detected in bodies of some birds which have been analysed for organochlorine compounds during the past three years. The source of these residues is not always clear. They have often been found together with residues of DDT. The " Rhothane " may have occurred as an impurity in the DDT used, or it may have resulted from the metabolism of DDT within the

birds. In the few cases where large residues of "Rhothane" alone have been found, the birds came from fruit growing districts in which the chemical is known to be used as such and may have been the cause of death.

36. Despite the fact that "Rhothane" is one of the less toxic organochlorine pesticides, evidence from the U.S.A. shows that it can build up in "food chains" to levels which are almost certainly dangerous to some species of birds.

V. DISCUSSION AND CONCLUSIONS

37. We have considered endrin, endosulfan, chlordane, "Toxaphene" and "Rhothane"; the possible effects of their uses on man and wild life; and the likely results of the withdrawal of these chemicals from current practice.

38. These chemicals are used in Great Britain to a much smaller extent than aldrin, dieldrin, DDT and BHC. For example, the amount of endrin formulated for use in 1962 was only one seventieth of the dieldrin so prepared.

39. This relatively small use is one possible reason why there have been comparatively few reports of harm to wild life by any of these pesticides and why residues have seldom been found in bodies analysed for organochlorine pesticide residues.

40. We have no evidence that current uses of endrin, endosulfan, chlordane, "Toxaphene" and "Rhothane" are contaminating the environment of man or wild life to any significant extent or that there is any need to curtail those uses. We have noted that some uses for which official clearance has been given, e.g. of endrin, have either not been put into effect or have been discontinued.

41. We recognise that with a reduction in the use of aldrin and dieldrin due to the restrictions placed on them, as recommended in our original report, there may be a marked increase, in the next few years, in the amount used of any one of the five pesticides examined in this Supplementary Report. We consider, therefore, that if the amount of any one of these pesticides shows a large increase in the near future, its use should be reviewed immediately. To this effect, industry should be invited to supply yearly over the next three years, under the same conditions of confidence on which they provided data on aldrin, etc., information on the tonnage of endrin, endosulfan, chlordane, "Toxaphene" and "Rhothane" formulated for sale in Great Britain.

Endrin

42. For the reasons given above and taking into account the general principles laid down in the original report, we consider that the use of endrin on non-fruiting blackcurrant bushes and propagating stock, and on fruiting blackcurrant bushes pre-blossom for the control of gall mite may continue as at present, as well as its use on apple trees up to petal fall for the control of insect pests, on strawberry plants after all the fruit has been picked, on blackberry canes pre-blossom and on narcissus grown under glass. On the other hand we have found no need for the use of endrin on pear and cherry

since other products are more convenient in use, nor for its use in thermal vaporizers, in resins, lacquers, coatings, paints and mouse tracking powders since other less hazardous products are equally effective for these uses and we suggest that such recommendations as cover these uses should be withdrawn.

Endosulfan

43. At present, recommendations have been made for its use on non-fruiting and fruiting blackcurrants (in the latter case not later than three weeks after first blossom appears), on strawberry plants after all the fruit has been picked and on non-edible crops. We see no reason to curtail these uses other than to suggest that use on non-edible crops should be restricted to narcissus grown under glass.

Chlordane

44. We see no justification for restricting the present uses of chlordane, namely for the control of earth-worms in turf and lawns and for the control of cockroaches and ants.

"Toxaphene"

45. This chemical is used only for the control of earth-worms in turf and in lawns and we consider that this use may continue.

"Rhothane"

46. We consider that its current, commercial use, for the control of insect pests on fruit trees and strawberries may continue.

General

47. As indicated in our original report we believe that every effort should be made to replace persistent chemicals by less persistent materials when these become available, and for this reason such uses of the chemicals considered above which continue should be reviewed at the end of three years.

48. In the meantime, every opportunity should be taken to evaluate fully the risks to wild life presented by the use of these chemicals.

49. Finally, we believe that there should always be the opportunity for new uses of these chemicals to be considered on their merits through the Pesticides Safety Precautions Scheme.

VI. RECOMMENDATIONS

50. We recommend that:

1. Endrin should continue to be available, for commercial use only, on propagating stock and non-fruiting blackcurrant bushes; on fruiting blackcurrant bushes (pre-blossom application only); on apple trees up to petal fall for the control of insect pests; on strawberry plants after all the fruit has been picked; on blackberry canes (pre-blossom application only) and for the control of bulb scale mite on narcissus grown under glass.

2. All other current commercial uses of endrin should cease as soon as this can be arranged.

3. Endosulfan should continue to be available, for commercial use only, on non-fruiting blackcurrant bushes; on fruiting blackcurrant bushes (applied not later than three weeks after the first blossoms open); on strawberry plants after all the fruit has been picked and for the control of bulb scale mite on narcissus grown under glass.

4. Chlordane should continue to be available for the control of earthworms in turf and lawns, and for the control of cockroaches and ants.

5. " Toxaphene " should continue to be available for the control of earthworms in turf and lawns.

6. " Rhothane " should continue to be available for current commercial uses in agriculture and horticulture.

7. If, in the near future, the amount used of any one of these pesticides shows a large increase, it should be reviewed immediately. Industry should be invited to supply, in confidence, information on the tonnage of each pesticide formulated for sale in Great Britain over each of the next three years.

8. The uses listed in recommendations 1, 3, 4, 5 and 6 should be reviewed at the end of three years.

51. Our recommendations for restriction of the use of endrin in paragraph 50.2 and for restriction of endosulfan, chlordane, " Toxaphene " and " Rhothane " to the current uses described in paragraphs 50.3–6, should not apply to research workers who might need to use these pesticides in their research and development programmes.

(Signed) J. W. Cook,

Chairman.

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REVIEW
of the
PERSISTENT ORGANOCHLORINE PESTICIDES

SUPPLEMENTARY REPORT BY THE ADVISORY COMMITTEE ON PESTICIDES AND OTHER TOXIC CHEMICALS

to the Secretary of State for Education and Science, the Minister of Agriculture, Fisheries and Food, the Minister of Health and the Secretary of State for Scotland

JULY 1964

LONDON
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CONTENTS

Chapter		Paragraph
	Composition of the Advisory Committee on Pesticides and other Toxic Chemicals (page iii)	
	Preface (page iv)	
I.	Introduction	1
II.	Their Uses in Agriculture, Horticulture and Home Gardens, in Food Storage Practice, Industrial Premises and the Home, and in Veterinary Practice	2
	Endrin	3–8
	Endosulfan	9–12
	Chlordane	13–14
	"Toxaphene"	15
	"Rhothane"	16
III.	The Hazards to Man	17–23
IV.	The Hazards to Wild Life	
	Introduction	24
	Endrin	25–29
	Endosulfan	30
	Chlordane	31–33
	"Toxaphene"	34
	"Rhothane"	35–36
V.	Discussion and Conclusions	37–41
	Endrin	42
	Endosulfan	43
	Chlordane	44
	"Toxaphene"	45
	"Rhothane"	46
	General	47–49
VI.	Recommendations	50–51

COMPOSITION OF THE ADVISORY COMMITTEE ON PESTICIDES AND OTHER TOXIC CHEMICALS

Formerly the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage

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PREFACE

1. In June, 1963, the Minister of Agriculture, Fisheries and Food invited the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage (as it was then called) to undertake a review under the following terms of reference :

> " In the light of existing information and that now coming to hand generally to review the risks arising from the use of chlorinated hydrocarbon pesticides (more particularly those containing aldrin, dieldrin and heptachlor) in agriculture (including gardening) and food storage and to make recommendations."

2. In February, 1964, the Committee presented to Ministers a report under these terms of reference with the title " Review of the Persistent Organochlorine Pesticides " (which by that time had become accepted as a scientifically more accurate description than " Chlorinated Hydrocarbons "). That report was mainly concerned with five pesticides, namely, aldrin, dieldrin, heptachlor, DDT and BHC. In paragraph 145 of the report the Committee stated that they had been unable to complete in the time available their review of five other pesticides, namely, endrin, endosulfan, chlordane, "Toxaphene " and " Rhothane ". They stated that a supplementary report covering these five pesticides would be submitted as soon as possible.

3. The report was published on 24th March, 1964, and on the same day the Minister of Agriculture, Fisheries and Food announced in the House of Commons that the Government had decided to give effect to the recommendations in that report.

4. The Minister also announced that the Government had decided to extend the Committee's terms of reference to cover the use of organochlorine pesticides for industrial and domestic purposes, such as wood preservation and mothproofing (to which the Committee had drawn attention) and also to enable it to report on other toxic chemicals which the Government might wish from time to time to refer to the Committee. In view of this extension of the Advisory Committee's responsibilities beyond that of agriculture and food storage it would in future be primarily responsible to the Secretary of State for Education and Science, although it would continue to advise other Ministers as necessary.

5. On the 18th June, 1964, the Secretary of State for Education and Science announced that pursuant to these decisions the title of the Committee had been changed to " The Advisory Committee on Pesticides and other Toxic Chemicals " and that its terms of reference had been extended—

> " To keep under review all risks that may arise from the use of—
> 1. Pesticides,
> 2. Potentially toxic chemicals on sale to farmers for veterinary use and veterinary medicines prescribed for use by veterinary surgeons, and
> 3. Any other potentially toxic chemical specifically referred to the Committee by Ministers,
>
> and to make recommendations to the Ministers concerned."

6. The Committee has now presented the present supplementary report referred to in paragraph 2 above. In view of the changes in ministerial responsibility it has been addressed to the Secretary of State for Education and Science, as well as to the Minister of Agriculture, Fisheries and Food, the Minister of Health, and the Secretary of State for Scotland.

I. INTRODUCTION

1. The problems raised by the increasing use of chemicals for the control of pests have attracted considerable attention since the end of the last war. The chemicals in question are rarely toxic only to the pests against which they are directed; therefore, they represent at least a potential danger to other plants and animals, including man himself. Scientists in universities, in industry and in Government service have been engaged on various aspects of research and there has been a great deal of discussion on the subject in the press, in Parliament and elsewhere.

2. Earlier official reports about the use of pesticides in Great Britain (by the Zuckerman Working Party on Toxic Chemicals in Agriculture) included general surveys of risks to workers applying pesticides (1951), of residues in food (1953) and of risks to wildlife (1955). These reports were followed by legislation or voluntary control measures. In particular, the regulations made under the Agriculture (Poisonous Substances) Act, 1952 now cover the risks at the time of application; and the Pesticides Safety Precautions Scheme which was agreed between Government and industry, together with the recently introduced Veterinary Products Safety Precautions Scheme, ensures that new pesticides or methods of use are not introduced unless considerable experimental work has been done in each case to provide the maximum assurance against a range of possible hazards, including contamination of food and harm to wild life. More recently there has been a study of the need for further research in this field [Toxic Chemicals in Agriculture and Food Storage. Report of the Research Study Group (1961)] which resulted in more work being done on particular aspects, and the setting up by the Agricultural Research Council of a Standing Research Committee on Toxic Chemicals, under the Chairmanship of Professor A. C. Frazer, which reports to the Minister for Science.

3. Notwithstanding these measures, there have been various expressions of disquiet. Experience with some pesticides has revealed information which, by its very nature, could hardly have come to hand until there had been a wide usage, but which then called for additional control measures. The pesticides in question are all organochlorine compounds which have been introduced since the war and are now employed on a wide scale. They have a common property which has often been overriding in their successful use for controlling insect pests, in that they are all fairly stable substances not readily changed into simpler and biologically inactive substances by the various mechanisms which commonly break down organic substances on exposure to natural conditions.

4. The new information has consisted largely of the finding, during recent years, of residues of certain of these pesticides (commonly referred to as "chlorinated hydrocarbons"), in many biological materials and in many environments beyond those to which direct application has been made. In particular, residues have been found in soils, in human beings and in domestic and wild animals. These animals, which include various mammals, birds and

fish, have sometimes been in remote localities, and for this or other reasons (such as their feeding habits) were not thought to be coming into contact with, or to be at risk from, the pesticides in question.

5. These findings are by no means confined to Great Britain: they have attracted much attention abroad, particularly in the U.S.A. Outstanding points at issue have been, firstly, whether man himself is being harmed by the residues which are finding their way into his body and, secondly, whether the contamination of natural environments (soil, etc.) and of wild animals is having undesirable effects.

6. Questions have been raised in Parliament on various occasions and, in a statement in the House of Commons on 19th June, 1963, the Minister of Agriculture, Fisheries and Food announced his invitation to the Advisory Committee to undertake this review. The terms of reference were:

> "In the light of existing information and that now coming to hand generally to review the risks arising from the use of chlorinated hydrocarbon pesticides (more particularly those containing aldrin, dieldrin and heptachlor) in agriculture (including gardening) and food storage and to make recommendations."

7. In considering the pesticides to review, we have not adhered strictly to the scientist's understanding of the term "chlorinated hydrocarbon", because we would thereby have excluded certain of the pesticides about which there has been much comment. In fact we have confined our attention to those pesticides specifically mentioned in the request, together with those other organochlorine pesticides which have often appeared in expressions of disquiet or which, because of their chemical stability or their wide use in Great Britain, appeared to warrant attention. Persistence has been taken into account, but this is a property which varies considerably with the various chemicals under consideration and according to the conditions to which they are exposed—for example *in* or *on* the plant, the animal, the soil or in water. The following pesticides were included in our studies: aldrin, dieldrin and heptachlor; DDT, BHC (including gamma-BHC or lindane) and "Rhothane" (TDE, DDD); endrin and endosulfan; chlordane and toxaphene. Appendix C contains information about the chemistry of these pesticides.

8. When considering our scope in the field of food storage, we found it convenient to adopt the definition recently agreed with industry for inclusion in the Pesticides Safety Precautions Scheme. It is as follows:

> "Food storage practice covers the use of any pesticide on food after harvesting or in premises where food is transported, stored or processed. It includes pesticides or techniques for their application (e.g. aerosols, vaporizers) in ships' holds, warehouses, food factories, wholesale and retail food stores, and in larders and kitchens in institutions and the home; it includes measures for controlling rodent, insect and mite pests which live on food and which may contaminate it, (e.g. rats and mice, weevils, flour beetles, flies, cockroaches and Pharoah's ants)."

9. We have not attempted to consider details of uses of these pesticides for any other purposes, such as against wood-borers in furniture and structural woodwork, against beetles and moths which attack fabrics in clothes and

furniture, or against insects such as midges, mosquitoes and bed bugs which are nuisances or of importance in public health. We have, however, drawn attention at certain places in this report to the possibility that such uses might provide some risk (e.g. by their contribution to certain of the residues found).

10. Our studies have been confined to the risks which might arise from the use of these pesticides *in Great Britain*, apart from some studies of pesticide residues in imported foods.

11. Throughout this report, the word "approved" is intended to signify the approval of a pesticide's efficiency against certain pests under the Agricultural Chemicals Approval Scheme (see Preface).

II. THE USES OF THE PERSISTENT ORGANOCHLORINE PESTICIDES

12. Pesticide chemicals have many uses and the manner in which they are formulated, and the strengths at which they are used, differ according to the purpose for which they are employed. The concentration of formulations available to commercial growers is generally greater than those retailed to home gardeners, and different formulations are often necessary for food storage practice. Sheep dips too are specially formulated for the purpose.

13. The uses can be conveniently divided into the following three parts:

(a) agriculture, horticulture and home gardens;
(b) food storage practice, industrial premises and the home;
(c) veterinary practice.

(a) *Use in agriculture, horticulture and home gardens*

14. All ten pesticides under review are used by commercial growers, but only six (viz. aldrin, dieldrin, DDT, BHC, chlordane and toxaphene) are retailed for home garden use. Part I of Appendix D gives the "approved" uses (=X), and names alternative pesticides for those uses, both "approved" and "non-approved" (=N.A.). Frequently the only "approved" alternative to one persistent organochlorine pesticide is another, and in several cases there is no "approved" alternative. Part II of Appendix D is concerned with uses "approved" for home garden use, and lists "approved" alternatives. We do not have sufficient information to list "non-approved" alternatives.

Aldrin and dieldrin

15. In 1957 official recommendations were made for their safe use as seed dressings, for soil treatment (including root dipping and sprays shortly after setting out), and for pasture treatment. Official recommendations were also made for direct application of dieldrin (subject to an interval of 6 weeks being allowed to elapse between application of the pesticide and harvesting of the treated crop) or indirect application (3 week interval) to that portion of the crop subsequently consumed. Restrictions on their use as cereal seed dressings were introduced in December, 1961 and still operate. Neither pesticide is regulated under the Agriculture (Poisonous Substances) Act, 1952.

16. The following table from Appendix E summarises the estimated annual usages of aldrin and dieldrin. Wherever possible, these estimates have been crosschecked, with good agreement, against confidential data supplied by manufacturers on the annual tonnages of active ingredient formulated for sale in the United Kingdom.

Acreages Grown, and Acreages believed treated with Aldrin/Dieldrin, England and Wales, 1962/63

Crop	Acreage grown in England and Wales, rounded to the nearest hundred	Acreage believed treated with aldrin/dieldrin as:		
		Aldrinated fertiliser	Sprays, dusts and drenches	Dips and seed dressings
Wheat	1,834,300	20,000	18,300	157,500
Barley	4,153,400	—	67,900	14,800
Oats	615,100	—	11,300	6,100
Maincrop potatoes	430,600	68,800	22,100	—
Sugar beet	408,400	—	—	204,200
Brassicae for human consumption	118,600	—	14,700	58,900
Carrots	31,300	—	25,900	4,600
Mustard	25,200	—	9,800	—
Strawberries	14,500	—	450	—
Dwarf and runner beans	13,500	—	100	6,400
Narcissus	7,700	—	—	630
Celery	5,800	—	600	—
Onions	5,300	—	—	100
Totals	7,663,700	88,800	171,150	453,230

Heptachlor

17. The official recommendations for this pesticide cover only its use as a cereal seed dressing for winter-sown cereals, and were made in December, 1961. There are no "approved" home garden uses of heptachlor, nor is it believed to be so available. Heptachlor is not regulated under the Agriculture (Poisonous Substances) Act, 1952.

DDT and BHC (including gamma-BHC)

18. Although we have examined these pesticides, no official recommendations have been issued, and neither pesticide is regulated under the Agriculture (Poisonous Substances) Act, 1952.

19. The table on page 5, from Appendix E, summarises the estimated annual usages of these two pesticides in England and Wales.

Endrin

20. Official recommendations on endrin were issued in December, 1957 for its commercial use on apples, pears and cherries and, in August, 1960, on blackcurrants. Endrin is regulated under the Agriculture (Poisonous Substances) Act, 1952 as a Second Schedule Part II Substance.

Endosulfan

21. Its use is at present restricted to commercial application to blackcurrants, and official recommendations were issued in March, 1963. Endosulfan is regulated under the Agriculture (Poisonous Substances) Act, 1952 as a Second Schedule Part II Substance.

Acreages Grown and Acreages believed treated with DDT and BHC, England and Wales, 1962/63

Crop	Acreage grown rounded to the nearest hundred	Acreage believed treated with DDT and BHC as:		
		DDT	BHC	
		Sprays and dusts	Sprays and dusts	Seed dressings
Wheat	1,834,300	29,700	12,900	608,200
Barley	4,153,400	10,000	118,700	1,082,900
Oats	615,100	7,800	3,800	249,800
Maincrop potatoes	430,600	14,800	2,100	—
Sugar beet	408,400	4,500	1,600	61,300
Edible brassicae	118,600	20,400	100	36,500
Brassicae for stock feed	392,300	—	—	216,900
Peas	118,700	24,600	—	—
Mustard	25,200	10,200	100	—
Soft fruit	35,300	13,600	—	—
Top fruit	186,900	119,600	58,000	—
Totals	8,318,800	255,200	197,300	2,255,600

Note: Soft fruit: Blackcurrants, strawberries and gooseberries.
Top fruit: Dessert and culinary apples, cherries, pears, gages and plums.

Chlordane

22. No official recommendations on its use, by commercial growers or the home gardener, have been issued. Its use as a worm-killer by both commercial and amateur users has however been agreed, and all firms known to be selling chlordane for this purpose have been advised of the precautionary phrases to go on the label of their products, which must not contain more than 25 per cent w/w chlordane. A comprehensive review of the use of chlordane is in progress. Chlordane, as yet, is not regulated under the Agriculture (Poisonous Substances) Act, 1952 although this is to be considered. No "approval" for the efficient use of chlordane has been given either for commercial or home garden use.

Toxaphene

23. The position of this pesticide exactly parallels that of chlordane.

"Rhothane"

24. This pesticide, also known as TDE and DDD, has been in use for some years but no official recommendations on its safe use have yet been issued. Nevertheless, as indicated in Part I of Appendix D, certain commercial uses have been "approved" for efficiency although this approval does not extend to home garden use, and it is understood that this pesticide is not available in retail packs. "Rhothane" is not regulated under the Agriculture (Poisonous Substances) Act, 1952.

Justification of usage

25. Appendix E includes a discussion on the extent to which the usage of the persistent organochlorine pesticides in England and Wales is justified. Some of the relevant data are presented in the table below. The annual acreage of the crops named in the table is approximately 8¼ million out of a total crop acreage (excluding grass and fallows) of 9 million.

Estimated Effectiveness of Organochlorines (O/C's) in the Field
(All data consolidated as equivalent acres per annum)

Crop	Pest	*Maximum likely loss*	*Possible average loss*	*Possible average annual loss if O/C's continue to be used as at present*	*Possible average annual loss if O/C's are not used at all*
Winter wheat .	Wheat bulb fly .	60,000	30,000	—	30,000
All cereals. .	Wireworm .	400,000	56,400	—	32,400
Sugar beet .	Wireworm .	172,000	10,300	—	10,300
Sugar beet .	Mangold fly .	20,400	5,100	—	—
Potatoes . .	Wireworm .	18,100	1,600	1,500	1,600
Potatoes . .	Aphids . .	25,800	3,700	—	—
Peas. . .	Moth and weevil	20,500	4,200	2,100	4,200
Edible brassicae.	Root fly . .	73,600	25,900	2,600	6,400
Brassicae for stock feed	Beetles . .	80,800	58,800	—	22,000
Mustard . .	Beetles . .	8,000	3,300	—	2,000
Carrots and celery	Carrot fly .	30,000	17,000	200	700
Culinary apples .	Caterpillars .	86,500	33,400	1,000	1,000
Totals . .		995,700	249,700	7,400	110,600

26. The conclusions drawn from these data and the associated discussion are:

(a) If chlordane, endrin, endosulfan, heptachlor, toxaphene and "Rhothane" were to be withdrawn from use, agricultural production would be little affected. Heptachlor seed dressings would be replaced by dieldrin seed dressings for cereals and sugar beet. Some soft fruit growers would change from endrin or endosulfan to lime-sulphur for blackcurrant gall mite control, pending the development of better substitutes. There may be some loss of efficiency here and annual costs might increase slightly.

(b) If aldrin and dieldrin were to be withdrawn as well as the materials mentioned above, there would be an annual loss of about 4,000 equivalent acres of winter wheat, and similar losses of cabbage and sugar beet. Some bulb, soft fruit, and vegetable growers might be effected to a certain extent. There would also be damage to about 17,000 equivalent acres of carrots, most of which could probably be made good by use of an organophosphorus pesticide. Again the cost would be greater than with the continued use of dieldrin.

(c) If in addition to the above, DDT and BHC were to be withdrawn, there would be an annual potential loss of about 250,000 acres of crop production in England and Wales. About 100,000 acres could be made good immediately by changing to alternative pest control materials which are already available. Possibly a further 75,000 acres could be made good within a short time by the extended use of materials which are at present more expensive than the persistent organochlorine pesticides. Examples are the organophosphorus pesticides menazon, disulfoton, azinphos-methyl and phorate. The final 75,000 equivalent acres might present more difficult problems (e.g. the development of reasonably persistent, non-phytotoxic, organophosphorus pesticides which are of low enough vertebrate toxicity to be used as soil pesticides without creating wild life hazards). This loss would fall most heavily on cereal, sugar beet and brassicae growers, though

a range of high-value horticultural and vegetable crops would also be affected.

(b) *Use in food storage practice, industrial premises and the home*

27. Of the ten pesticides being reviewed only aldrin, dieldrin, gamma-BHC, DDT and chlordane are used in food storage practice, which broadly covers four main fields. The two fields which probably comprise the major use of pesticides in food storage practice are the control of insects, mites and rodents directly infesting or living in foodstuffs and the control of those pests which may invade foodstuffs (e.g. cockroaches, ants and rodents). The third field is the use of pesticides against certain public health insects such as flies and mites, and the fourth is their use in the home against a wider range of pests, including those covered by the other three. It has not been possible for us to estimate the proportion of pesticides used in the home, compared with the other uses mentioned.

28. Losses from insect infestation can threaten the foodstuff from harvest to consumption and, for the protection of food during storage, various species of insects have to be dealt with under conditions very different from those in agriculture. Hazards from the treatment of the stored product are confined to the operator applying the pesticide and to the consumer of the food. There are no significant risks to wild life, except those due to accidents or negligence (mainly in the disposal of surplus materials and containers). In suitable conditions fumigation provides much of the control of stored products insects. When properly used, fumigants leave little or no residue in foodstuffs, but special care is needed to protect the operator during treatment. Contact insecticides are safer to apply but, owing to the tendency of some to leave persistent residues, only a few are commonly employed in food stores and handling premises, etc., and these have special properties which make them interchangeable to only a very limited degree. The official recommendations for their safe use are aimed at keeping any residues well below those considered to present the slightest hazard.

29. Because stored foodstuffs are at risk from insect infestation for considerable periods, some persistence of the insecticide is desirable during this period, otherwise the cost and difficulty of frequent re-treatment would be prohibitive. Usually the treatment is given to the structure of the store and not directly to the foodstuff itself, and even when it is applied other than to the structure the foodstuff receives only partial treatment because of protection by containers, such as sacks and cartons.

30. With a few exceptions, there has been no problem in Great Britain of food storage insects becoming resistant to any of the organochlorine pesticides. Nevertheless in other countries some of these insects have acquired resistance to organochlorine or to organophosphorus pesticides. Such insects may be brought to this country as a result of their carriage on food commodities in international trade. The choice of pesticides suitable for use in the protection of stored foods is extremely limited, and the development of pest resistance to any of them would pose serious problems because of the lack of alternatives. Even if current information suggests that there might be a case for restrictions on the use of some organochlorine pesticides, the problems of resistance and limited choice must be given serious consideration.

31. While some of the pesticides used in food storage practice are available in a limited number of formulations, others are used in a variety of ways. Dieldrin and DDT, for example, may be used in oils, aqueous emulsions, wettable powders, dusts, resins, paints, aerosol pressure packs, thermal vaporizers and smoke generators. The more specialised formulations are normally used only by servicing firms and local authorities, but many of the others are freely available in most pharmacists, ironmongers and multiple shops, where they are sold for a wide variety of uses including the control of flies, ants, cockroaches, earwigs, woodworm, clothes moths, carpet beetles, bed bugs and similar household pests. Carpets and clothing fabrics are also treated for moth-proofing. The Notification of Pesticides Scheme provided us with no opportunity to consider uses other than in food storage, but the Scheme as now revised (and re-named the Pesticides Safety Precautions Scheme) will present an opportunity for requesting information on a greater variety of uses. Little is known about the user, consumer, or third-party hazards likely to exist or arise from the use of these formulations under a variety of conditions in the home.

Aldrin

32. Aldrin has never been officially recommended for use in food storage practice, and its employment has been limited to inclusion in insecticidal resins, lacquers, coatings or paints. These formulations were reviewed and revised official recommendations issued in January, 1962. Aldrin does not appear to be particularly effective in resin formulations and little disadvantage would arise if this pesticide were deleted in any future revision of the official recommendations for such formulations.

Dieldrin

33. The use of dieldrin in food storage practice was first considered in 1956, when limited evidence was available from industry on the efficacy or potential hazards of the pesticide in practical usage. In 1961 the residues which could result from typical treatments were assessed on the basis of the quantities of pesticide and of foodstuff respectively involved. It was then agreed that dieldrin should not be used for some of the situations (e.g. empty grain bins) covered by the original official recommendations then in use.

34. Although dieldrin has been available for at least seven years, it has been used only on a very small scale for the control of food storage insects (except for cockroaches and ants, mentioned below). This is primarily because the precautions advised for its safe use are more stringent than for some other pesticides, but also because one or two (e.g. malathion and gamma-BHC) are more effective for specific purposes. For these reasons, the food industry would be unlikely to be handicapped if dieldrin were withdrawn for the control of crawling insects likely to infest raw and processed food in commercial stores.

35. Dieldrin has had a substantial share of the market in recent years for the control of cockroaches. It has been officially recommended for this purpose, but recent evidence has shown that in some areas the German cockroach [*Blattella germanica*] has developed resistance to this pesticide. The other common cockroach in Great Britain, the oriental cockroach [*Blatta orientalis*] has shown no such resistance and, because dieldrin has probably been the most successful contact insecticide for cockroach control, there is a continuing

need for its use to control cockroaches other than the resistant German cockroach. It is also widely recommended and successfully used for the control of ants (e.g. *Monomorium spp.*) in buildings.

36. Dieldrin has also been used in pellet form in thermal vaporizers. These vaporizers generally use gamma-BHC, but occasionally DDT or a mixture of DDT and gamma-BHC. Thermal vaporizers may be run continuously, or be switched on periodically (e.g. overnight and at weekends), and are claimed to control practically all flying or crawling insects. They are used in houses, restaurants and shops. Our Scientific Subcommittee had already requested from industry data on thermal vaporizers so that their safe use might be reviewed towards the end of 1964.

37. Dieldrin is also used in dry sugar baits for wasp control. Occasional damage to bees has been known to occur from such use.

DDT

38. DDT originally had a wide use for the control of many stored products and public health insects and mites, but lately it has been replaced partially by pesticides such as dieldrin and certain organophosphorus compounds. It is still used against house-flies, blowflies, cluster flies, silver fish, wood-boring insects and clothes moths. Pyrethrins are often included in DDT formulations for these uses. DDT continues to be widely used in food factories, food storage premises, shops, restaurants and domestic premises. Small packs are available to the domestic user, and the labels in some instances leave much to be desired.

39. An important use of DDT is to control house-flies and blowflies, except where the former have become resistant to this chemical. DDT (sometimes with pyrethrins) is used for residual treatment of walls and similar surfaces. In slaughterhouses DDT dusting-powder may be applied to all non-edible offal, to manure heaps and to other sites where flies may rest. A water dispersible powder suspension of DDT may be sprayed or brushed on to the slaughterhouse walls. DDT may also be used for fly control on refuse tips, for which purpose quite high dosages may sometimes be applied; fly resistance to DDT, however, is fairly common on such sites.

40. DDT has never been officially recommended for admixture with cereal grains, nor for direct application to foodstuffs. It has, however, been recommended for application to the walls of warehouses, farm grain stores and similar places. Malathion or gamma-BHC have largely replaced DDT for the treatment of such surfaces, for the control of stored products insects.

41. Official recommendations for the safe use of DDT in food storage practice were drawn up in 1963 but have been held in abeyance by Departments pending completion of this review. Any restriction on the use of this pesticide in food storage practice would have to recognise a possible future need for its use against insects acquiring resistance to alternative pesticides.

gamma-BHC

42. gamma-BHC has had an extensive use in food storage practice. It is effective for the control of some crawling insects, moths and mites and is particularly toxic to insect eggs. A similar range of formulations to those available for dieldrin and DDT is currently in use both commercially and in

the home. It is compatible with most other pesticides used in food storage practice and is used occasionally, but not extensively, in this country for admixture with stored grain. As with DDT, official recommendations drawn up for the safe use of this pesticide have been held in abeyance pending completion of this review.

Chlordane

43. Chlordane has been used for many years in food storage practice; almost entirely for the control of cockroaches and ants. Its use has diminished in recent years following the introduction of dieldrin formulations for the same purposes. There is, however, a continuing use of chlordane for cockroach and ant control, particularly by some servicing firms.

(c) *Use in veterinary practice*

44. In Great Britain, the most important external parasites of sheep are blowflies (particularly *Lucilia sericata*) and ticks. Blowflies are responsible for the condition known as "strike" (myiasis) in which the sheep is parasitized by the larvae of the blowfly. Ticks cause damage by irritation, loss of blood, secondary infection of the wounds, and because they act as vectors of viral, rickettsial, and bacterial diseases. In cattle, ticks are responsible for the transmission of a protozoal parasite, *Babesia divergens*, which causes a disease known as "red-water". They also transmit a species of rickettsia which causes "tick borne fever". Sheep scab is caused by the mite *Psoroptes communis ovis*. There are in addition several other external parasites of domestic animals such as keds, fleas, lice, and other species of parasitic mites, which are of relatively less importance.

45. The use of pesticides is essential to control these parasites, particularly on sheep. Up to the time of the last war, control was unsatisfactory and blowfly, for example, was an exceedingly serious hazard to the sheep industry. The introduction of persistent organochlorine pesticides such as BHC enabled both "strike" and sheep scab to be controlled to a substantial degree. The later introduction of dieldrin, a pesticide of greater persistence, meant that blowflies could be controlled by a single annual application.

Position prior to the introduction of persistent organochlorine pesticides

46. Accurate and comprehensive figures are not available but the following information indicates the extent of the problem. According to Mackerras (1938) the incidence of "strike" in Great Britain was surprisingly high considering the small wool production per head (i.e. the smallness of the fleece) and the relatively cold climate. In North Wales where the counties of Anglesey, Caernarvon, Denbigh and Flint carried over a million sheep, Davies (1934) considered that, although the loss by death was small, there was a considerable loss of time and expenditure in attending to "struck" sheep, especially in a bad year when 30 to 40 per cent of a flock might be affected. In Scotland it was the opinion of flockmasters that blowfly "strike" was gradually becoming worse and involving areas previously untroubled by the blowfly. Haddow and Muirhead-Thomson (1937) stated that in a flock of 1,000 sheep the owner lost 81 by death from "strike" in one year. The incidence of "strike" varied greatly from year to year. The following figures have been recorded:

Morison (1937)—Incidence 12 per cent.
Miller (1935)—Incidence 15 to 20 per cent.
Ratcliffe (1934)—Incidence 34 per cent in 1933; 27 per cent in 1934.

47. Ratcliffe (1934), by means of a questionnaire sent to sheep farmers in various parts of Scotland, obtained some information regarding the cost of the blowfly to the industry in 1933. The estimates were very variable, ranging from nil to £300 per flock. The figures, given below, include the value of animals which died, the estimated depreciation in market value of affected animals, and the cost of the dips and dressing.

Size of flock	*Estimated loss*
	£
400 ewes, plus lambs	40
1,000 ewes, plus lambs	104
1,400 ewes, plus lambs	150–170
900 sheep	72
6,500 sheep	300
900 ewes, plus lambs	113
2,400 sheep	20
500 ewes, plus lambs	11
1,400 sheep	5
400 ewes, plus lambs	19
1,200 sheep	25
1,700 sheep	82

48. Omitting those estimates in which the number of lambs is not stated, there are figures from six farms which, if added together, give the loss on 14,100 sheep as £504. This is roughly £35 per 1,000, or 8d per head. MacLeod (1937) estimated the loss at 1s. per head of adult stock.

49. In 1934, there were approximately 24 million sheep in Great Britain. Calculated at the rate of £35 per 1,000, the loss would have been approximately £840,000. Even allowing for the fact that the incidence of "strike" would be variable over the country as a whole, annual losses must have been several hundred thousand pounds sterling.

50. Dips in use at that time contained carbolic acids, sulphur, arsenic and derris. The maximum protection period was about 3 weeks but this could be much less, and there was some evidence that the blowfly season was becoming longer.

51. Sheep scab, a notifiable disease, was controlled by procedures laid down in Orders under the Diseases of Animals Acts, but it was not until the introduction of the persistent organochlorine pesticides that eradication became a practical proposition.

Present position

52. Sheep scab has been eradicated from England, Wales and Scotland. Legislation still exists, particularly to prevent its reintroduction through the importation of affected sheep.

53. As regards the control of other pests, after DDT and BHC began to be used in the mid 1940's, DDT killed the adult blowfly and gave 6–7 weeks protection at a strength of 0.5 per cent BHC, on the other hand, gave very little protection against the adult blowfly itself but at a strength of 0·016 per cent was an efficient larvacide. Protection with this compound lasted about

6 weeks. In the 1950's dieldrin became generally available and thereafter was used extensively because of its long period of larvacidal activity (12–20 weeks). In most circumstances and seasons, one dipping in this pesticide afforded flock protection throughout the whole of the "strike-risk" period during the summer months. This resulted in less dipping, a big decrease in the shepherding and inspection of flocks and in the reduction of losses accruing from "strike" to very small proportions.

54. At the end of 1960 the total number of dips approved under the Sheep Scab Orders (which require either single or double dipping according to the pesticide and formulation being used) was 219, of which 153 were single dips. Of the 66 approved double dips, 48 were based on tar oil or tar acid mixtures, and 18 on arsenic. The latter consisted of concentrates with a high arsenic content for use at a dipping-bath concentration of approximately 0·2 per cent arsenous oxide. The single dips approved under the Sheep Scab Orders all contained BHC and were formulated to give a dipping bath concentration of at least 0·016 per cent gamma-BHC when diluted. About a third of the approved single dips also contained DDT at concentrations designed to give dipping-bath concentrations of 0·2 to 0·6 per cent DDT.

55. Only one fifth of the approved single dips contain dieldrin (in addition to BHC), and are designed to give dipping-bath concentrations of 0·02 to 0·05 per cent. However, the majority of farmers are using those single dips which contain dieldrin.

56. We understand that the contamination of water by the disposal of used fluid from sheep dipping tanks may be controlled by the Rivers (Prevention of Pollution) Acts. From 1st June 1963, it became an offence to allow any potentially toxic effluent to flow into or contaminate a water course, unless with the consent of the River Board concerned.

Possible effect of withdrawal

57. If dieldrin were to be withdrawn, reasonably good control of blowfly would still be obtainable with, for example, BHC or DDT although in many parts of the country, and depending on weather conditions, more than one dipping or spraying would be necessary. Alternatives could include a return to the relatively hazardous dips and sprays containing arsenic, or the adoption of dips and sprays containing such organophosphorus pesticides as diazinon and dioxathion of which there is very limited experience under conditions in Great Britain. Experience in Australia and New Zealand, however, suggests that these pesticides would be more expensive than dieldrin, and that they would not provide the complete seasonal protection which farmers have come to rely on when using dieldrin.

58. The effects of withdrawing persistent organochlorine pesticides would be an increase in shepherding and labour costs on the sheep farm, additional expenditure on sheep dips and sprays, and less complete protection and thereby increased suffering by sheep, with a possible rise in economic loss from disease.

59. Our Scientific Subcommittee's Panel on Residues of Pesticides in Foodstuffs has examined samples of foodstuffs which fell into two classes; those in which a detailed history of pesticide treatment was known, and those in which this was either unknown, uncertain, or only of a general nature. The first class comprised samples of home-killed mutton kidney fat taken from animals whose pesticide treatment was known, and samples of potatoes from fields where the soil pesticide usage was also known. In the second class were home-produced butter and milk (taken from bulk supplies at creameries in various parts of the country) and all the imported foodstuffs, the latter being sampled at the bulk-supply stage.

60. The studies so far conducted on residues of organochlorine pesticides have dealt with dieldrin, DDT and BHC in butter, milk, mutton kidney fat, beef fat and potatoes. These foodstuffs were also examined for residues of heptachlor epoxide but measurable quantities could not be detected except in the case of milk, where traces were found although these could not be firmly identified as heptachlor epoxide.

61. All analyses were made using gas chromatography. It must be understood that where this technique was used at or near the limit of its sensitivity, as with the milk, butter and potato samples, no other method of analysis, of comparable sensitivity, was available to confirm the presence and identity of all the residues indicated. Whenever possible, paper chromatography (and in a few cases infra-red spectroscopy) was used to confirm the identity of certain of the residues detected and measured by gas chromatography.

62. The results of these initial studies, which are summarised in Appendix F, show that persistent organochlorine pesticides were present in each group of foods examined. In that Appendix, all reference to dieldrin residues should be taken to include any which have arisen from aldrin.

63. The samples of home-produced mutton kidney fat all came from animals marketed at comparatively short intervals after dipping and included some with rather high dieldrin residues. We are of the opinion that the high residues found would not reflect the general situation because longer periods than those deliberately chosen for these studies usually elapse before dipped sheep are sent for slaughter. Undesirably high residues may, however, occur in sheep slaughtered a month or two after dipping in the spring or early summer. It is unlikely that such meat would contribute appreciably to the diet throughout the whole year.

64. We recognise that the studies so far have been almost exclusively on meat and animal products and that, apart from potatoes, vegetable crops have received little attention. However, we concluded from the results available that sheep dips containing aldrin/dieldrin may represent one food source of the residues of dieldrin found ultimately in human fat. The use of aldrinated fertilizers in potato growing is in our view probably another significant source.

65. Residues of dieldrin have been found in imported meat from animals said not to have been treated with dieldrin dips or sprays. We are of the opinion

that information is required on the origin of such residues and of those organochlorine residues found in animal products.

66. We agree with the Panel that further studies, especially of vegetable crops, are needed before any firm opinions can be given on the food sources of organochlorine residues found in human fat. Studies are also needed on other possible contributory sources of these residues, certain of which may arise from uses other than in the agricultural field. The available results for residues in food do not lead to any disturbing conclusions in respect of the use of DDT and BHC in food production, but further studies are needed on a wider range of foodstuffs.

67. The examination of the mutton kidney fat samples indicates that current practice may occasionally lead to undesirably high levels of dieldrin in human food. The need for such uses of dieldrin should therefore be critically examined. Even low levels of dieldrin in a basic food like potatoes must be considered undesirable if the crop can be produced without such residues.

68. For both aldrin and dieldrin, we have concluded that their presence in foods should be reduced and, in order to achieve this, certain practices (their use in dips and sprays for sheep, and in fertilizers for potatoes) need to be curtailed.

IV. THE HAZARDS TO MAN

69. The organochlorine pesticides currently in agricultural use have been comprehensively studied by the conventional methods used to demonstrate mammalian toxicity. In the U.S.A. and in other countries, agreement to their use has only been given on the basis of information supplied on their toxicity to a number of laboratory animals in both short-term and long-term experiments. None of these compounds appears to have presented any special problems in that their use in agriculture was readily accepted and, in the U.S.A., residue tolerances were set.

70. In recent years, the question has been raised as to whether or not the uses of these organochlorine pesticides are really as free from hazards to man as had originally been supposed. Though in part arising from the claims that certain wild species were being adversely affected, the main basis for some renewed anxiety can be considered under three main headings:

Statements in the book "Silent Spring" (Carson, 1962) which imply that the organochlorine compounds used as pesticides in agriculture are powerful liver poisons.

71. Simple organochlorine compounds such as chloroform, carbon tetrachloride and tetrachloroethane (which are true chlorinated hydrocarbons) are well known liver poisons and can kill or injure mammals by virtue of the damage they do to the liver. Such injury may occur in an animal which has been given one of these compounds as an anaesthetic. Carbon tetrachloride is used to a limited extent in fumigation, and adequate protection of the

operator is necessary because of the anaesthetic and potential liver and kidney-damaging effects of this compound. Not all chlorinated hydrocarbons damage the liver and a well known example of one that does not is trichloroethylene.

72. With the exception of carbon tetrachloride, those organochlorine compounds used as pesticides exert their toxic effects on mammals and insects by disturbing nervous activity. Animals fatally poisoned by these compounds die in convulsions or, in the case of DDT, with widespread tremors and disorganised muscular activity. When animals die in this way after single doses of these pesticides, some histological evidence of liver injury is usually observed. However, this is not the cause of the death of the animals and if they just survive a dose of an organochlorine compound they do not subsequently develop a serious or fatal liver necrosis. Even with repeated administration of dieldrin by addition to the diet at levels that will cause some rats to have occasional convulsions, no serious liver damage is observed. Animals receiving dietary doses of organochlorine compounds for long periods do show some increase in their liver weight. This is due to an increase in the size of the centrilobular hepatic cells, and the change has been compared to that of a "work hypertrophy" because it may be associated with the increased demands on the liver to metabolise these insoluble materials so that they can be excreted.

73. It has been claimed that definite cytological changes can be detected in some liver cells in some rats receiving as little as 5 p.p.m. DDT in their diet. The significance of these cytoplasmic inclusions (lipospheres) is difficult to appraise since they are not seen in other species; nor are they always reproducible in different laboratories or at different times in the same laboratories. These changes certainly do not represent a serious or irreversible change in the liver cells. Fibrosis and similar chronic liver lesions are not seen in animals given organochlorine pesticides in their diet during their life span.

74. Many men, mainly engaged in public health programmes to eradicate malaria, have been poisoned by dieldrin to the extent of having serious or repeated convulsions. Smaller numbers of people have been poisoned when DDT or BHC has been swallowed, usually in error after addition to food. In no case is there a report of the subsequent development of the signs and symptoms of liver injury.

75. Thus, excepting carbon tetrachloride, there is no basis at all for calling the organochlorine pesticides as a class severe liver poisons, either for man or for animals.

Experiments on rats and mice in the Laboratories of the Food & Drug Administration (F.D.A.) in Washington have led the investigators to describe DDT, aldrin and dieldrin as having a "weak carcinogenic" or "slight tumorigenic" potential.

76. On the basis of the published results, some people fear that these compounds will present a carcinogenic hazard to people who are exposed to them. The experiments on rats with DDT were published 12 years ago yet the officials of the United States F.D.A., in whose laboratories the observations were made, have never pressed for the exclusion of DDT on the grounds that it might be a carcinogen, even after the passing of the Delaney Amendment. [This states that "no additive shall be deemed to be safe if it is found to

induce cancer when ingested by man or animal, or if it is found, after tests which are appropriate for the evaluation of the safety of food additives, to induce cancer in man or animals"]. The experiments on mice with aldrin and dieldrin were reported only last year, nevertheless there have been some views expressed by U.S. scientists that aldrin and dieldrin may be designated as carcinogens. In the conventional two year studies on rats with DDT, aldrin and dieldrin, investigators in other laboratories have never reported evidence of liver tumour formation despite the fact that in very large doses these compounds can produce some liver injury as discussed above. Thus it is necessary to consider whether published evidence is a sufficient basis for calling DDT a carcinogen for rats, and aldrin and dieldrin carconogenic for mice. It is certain that none can be described as an indisputable carcinogen, on the other hand there would probably be no dispute among pathologists that carbon tetrachloride is a liver carcinogen for mice though probably not for rats. The mild wording used by the authors of the papers on DDT and on aldrin and dieldrin indicated the reservations they seem to hold. Pathologically the lesions are not indisputably malignant. Slides from the mice used in the experiments with aldrin and dieldrin were seen by several pathologists in this country including those who are on the Ministry of Health Panel on Carcinogenic Hazards. There was no consensus of opinion that these represented malignant liver tumours. In both experiments the control animals had a certain incidence of liver tumours. While it might be considered a sound policy to treat everything capable of producing tumours of any type under any experimental conditions in any strain of animals as a potential hazard to man, too strict an interpretation of such a policy could lead, for example, to the exclusion of glucose or salt from the diet.

77. It has already been noted that the incidence of liver cell changes in animals fed organochlorine compounds varies somewhat from laboratory to laboratory, and so too does the incidence of hepatomata. At present there is neither the experimental nor the histological evidence upon which all competent pathologists would agree that DDT and dieldrin are carcinogenic for rats and mice respectively. Certainly on the basis of the evidence so far published, there is no good reason for condemning them as presenting a carcinogenic hazard to man.

Measurable quantities of DDT and dieldrin have been found in the body fat of members of the general population not occupationally exposed to these pesticides.

78. Over 10 years ago it was reported that DDT* was present in the body fat of members of the general population of the U.S.A. In the last two years surveys in Western Germany and the U.K. show an average level somewhat less than that found in the U.S.A. In both the U.K. and the U.S.A. substantially the same low levels of dieldrin have also been found. Data on dieldrin in Western Germany are not yet available. The source of the DDT in the American subjects was shown to be that present in the animal fat of food generally available. The sources of DDT and dieldrin in the U.K. subjects have not yet been determined.

* In this context DDT will include the varying proportion found as its metabolite DDE. This may represent more than 60% of the whole. It is not toxic to mammals or insects.

79. Evidence has been sought as to whether the DDT could have any injurious effects while it remains in the fat. The metabolic activity of fatty tissue *in vivo* and *in vitro* has been studied in normal rats and in rats fed DDT in their diet so that the level in their fat reached about one hundred times that found in man. No differences were found between the behaviour of normal fat and fat containing DDT, dieldrin or BHC. Furthermore, the DDT was present in the fat at a concentration which, if it were added to cell mitochondria metabolising in isolation, would have disturbed their activity. Apparently the mitochondria of the fat cells remain unaffected by the high level of DDT in the fat globules in the cytoplasm of the same cells. That the DDT is still pharmacologically active is shown by the fact that rats in which DDT is present in very high concentrations in their fat will show signs of poisoning if their food intake is reduced and their fat has to be rapidly mobilised. DDT is harmlessly stored in the fat and slowly released if intake ceases, but the level in the body fat is five to ten times as great as that in the whole diet. Dieldrin, heptachlor (as heptachlor epoxide) and BHC are also laid down to some extent in body fat but not to the same levels as DDT. The basis upon which fat storage takes place is not known but probably depends in part on the relative lipid-water solubility of the material. There are very big differences in the extent to which the different isomers of BHC are laid down.

80. The significance of this deposition of organochlorine pesticides in human fat must be considered. While it is perhaps undesirable on aesthetic grounds that our body fat should contain traces of DDT, there is no scientific evidence that the DDT does any injury while it is in the fat. It neither disturbs the activity of the fat tissue itself, nor is it free to injure the sites that are sensitive to its action. However, new information about the biological action of DDT may emerge at any time. For example, very recent work has shown that rats on diets containing 10 p.p.m. DDT store less Vitamin A in their livers than normal rats. Some process common to the metabolism of both Vitamin A and carotene seems to be disturbed in rats receiving DDT. The importance of these observations cannot be assessed at the moment, but as Vitamin A has been implicated in other detoxication mechanisms carried out by the liver, it is probably not an effect seen only after intake of DDT. Clearly more work on this newly observed response to DDT is needed.

81. During the 10 years in which observations on the levels of DDT in the fat of U.S. citizens have been made, there has been no evidence of an increased exposure. The same sort of consideration applies to inhibitors of blood cholinesterase. It is generally accepted that small depressions of blood cholinesterase activity do not reflect an actual injury, but such measurements provide a sensitive index of exposure enabling hazards to be controlled. A highly reactive alkylating agent may be much more injurious but leave no trace of its passage through the tissues for biochemists to detect with the means now available to them.

82. A great deal is known about many of these substances, and their presence may be detected in concentrations many times smaller than those known to be toxic. Man may be safer when exposed to these substances than to new materials which appear safer because they behave differently when tested on animals, but for which no sensitive means for detecting their full effects have yet been discovered.

V. THE HAZARDS TO WILD LIFE

Introduction

83. Evidence submitted to us by various organisations was considered in detail by our Scientific Subcommittee and its Wildlife Panel: other (mostly published) information was also considered.

Seed Dressings

84. Although it is possible that organochlorine pesticides may previously have had some effects on wild birds and other animals, it was not until 1956 that any of their uses in Britain became suspect on this account. In that and the following years increasingly large numbers of seed-eating birds were found dead in cereal growing areas in spring. In each year, starting in 1960, the Royal Society for the Protection of Birds (R.S.P.B.) in conjunction with the British Trust for Ornithology (B.T.O.) issued reports on such incidents, and the occurrences received wide publicity. At the time there was much speculation as to the causes, and investigations undertaken by the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food, showed that aldrin, dieldrin and heptachlor used to dress cereals sown in spring were almost certainly responsible for the deaths amongst birds, and probably also for some consequential poisoning of mammals. It was therefore agreed in the summer of 1961 that these dressings should not be used on spring-sown cereals and that in autumn they should be restricted to cereals in districts where there was a real danger from wheat bulb fly [*Leptohylemyia coarctata* (Fall.)]

85. This voluntary agreement, which was negotiated with manufacturers and distributors of pesticides under the "Pesticides Safety Precautions Scheme", has been renewed each year since 1961 and appears to have been well honoured in practice. There has been no evident recurrence of the incidents since 1961.

86. No evidence has come to hand which seriously implicates BHC, and no restrictions have been placed on the use of this pesticide. It was used in dressings for cereals prior to 1956, when aldrin and dieldrin were introduced and when the first outbreaks were noticed, and has continued in use since 1961 when aldrin, dieldrin and heptachlor (which was introduced in 1958) were withdrawn.

Other Uses

87. We have found very little information, other than for seed dressings, by which deaths amongst wild birds or other animals in the field can clearly be linked with specific uses of these organochlorine pesticides. The First Joint Report of the B.T.O./R.S.P.B. Committee (1960), for example, refers to eight incidents "where sprays were alleged to have killed birds and animals" and the Second (1961) and Third (1961/62) Reports refer to thirty-two and forty such incidents. In most of these cases, however, the evidence for pesticides being the cause of the deaths in question is very inconclusive, and the increase in the numbers of allegations in the respective reports appears only to reflect the increased public interest.

88. Although the enquiries by the Infestation Control Laboratory and the Regional Pests staff of the Ministry of Agriculture since 1961 have included

investigations into cases where specified uses of organochlorine pesticides, other than as seed dressings, have been alleged to produce casualties, only on very few occasions has the evidence suggested that such uses were responsible.

89. Much caution is needed in assessing such information, because the possibility of establishing a link between a given application of a pesticide and any effects on birds in the field is influenced by the speed of the onset of symptoms. If the effects are delayed beyond a few days, or if a series of dosages over a period may be responsible for symptoms, any link with the intake of poison may not be apparent to an observer in the field. For this reason assessment has often had to be based on observations on populations and on the finding of residues in bodies, and it is not always possible to reach clear-cut conclusions as might be the case when casualties clearly follow specific applications in the field.

Significance of Residues found in Bodies and Eggs

90. When considering the data on residues of pesticides found in bodies, eggs and other biological material, we have had to take into account that very great improvements in analytical techniques have taken place recently which enable residues, which hitherto would have passed without detection, now to be measured with accuracy. We have also noted that the introduction of new techniques and widespread interest in the subject have together resulted in an increase in the number of occasions on which measurable residues have been found.

91. Experimental or other data, which are essential for understanding the significance to an individual bird or other animal of a residue found in its tissues or organs, are often lacking. Experiments have been undertaken on the acute toxicities to various species of the various pesticides under review, and in some instances the residues found in stated organs or tissues have been measured after the administration of known amounts: measurements in feral pigeons at the Infestation Control Laboratory of the M.A.F.F. and in Japanese quail at the Patuxent Research Laboratory in the U.S.A. are examples. Few data are available however on the effects of the continued administration of low doses and the residues to be found in bodies after such administration. Our knowledge of the rates at which residues of the different organochlorine pesticides build up during dosing and subsequently disappear from the bodies of live birds is also very limited.

92. The importance of residues found in eggs is also difficult to assess. Various workers have shown experimentally that organochlorine pesticides at sub-lethal levels can reduce egg production and fertility, but these effects do not appear to occur below certain levels of intake and when the residues in the eggs are low. Work is currently being done to obtain further information on this aspect.

93. In the light of these uncertainties, the results of chemical analyses of bodies of birds or other animals from the field must be considered with great circumspection. Although it is hardly ever possible to base a firm conclusion as to the cause of death of a particular bird or egg upon the residues figure alone, chemical examinations do however provide valuable information; for example, in confirming or rejecting other evidence that a pesticide may be

responsible for observed effects, or to provide information on the distribution of the respective pesticides in different species and environments.

Distribution of Residues

94. Although we consider that the increases in the numbers of bodies of birds showing residues, and included in recent reports, largely reflect increasing activity and increasing accuracy in the discovery of residues, and although we are of the opinion that many of these residues were too small to provide likely explanations for the deaths of the birds in question, we are impressed by the wide distribution of these residues, particularly of dieldrin and of metabolites of DDT, in natural environments, and with their high incidence in certain species. The information on residues in soils, and in predatory and fish-eating species of birds, have specially attracted our attention.

Residues in Soil

95. Certain organochlorine pesticides can persist in soils for many years. The rate of loss varies from soil to soil and the various pesticides disappear at different rates. Following the use of these pesticides in the field during recent years, large areas of agricultural land contain residues in small or large amounts. We have no precise information on the distribution of these residues in soils in Great Britain at present but it appears likely that, with present usages, their amounts are increasing.

96. Apart from any risks through crops picking up residues from the soil, the long term effects of this build-up have not yet been fully studied. Possible unforeseen effects are: (i) the soil might become less productive owing to the destruction of some of its fauna; (ii) when picked up by invertebrates (worms, slugs, etc.) the residues may become a danger to birds and possibly other vertebrates, and (iii) water may become contaminated by run-off and seepage and aquatic organisms may pick up residues.

97. Although some research has been done on these questions (for example, some invertebrates have been shown to pick up small amounts of pesticide, and some fish taken from waters previously thought to be free of pesticide have been found to contain residues) a very considerable amount of work would be needed to elucidate the various consequential effects which may result from build up of residues in this manner. By the time that this work has been done undesirable effects may well have occurred already and we consider that this situation supports a case against the unnecessarily widespread application of highly persistent pesticides to the soil.

Predatory and Fish-Eating Birds

98. Observations in the field have shown that very marked declines have occurred in populations of various predatory birds in Britain during recent years. With certain species there are detailed records of nests and of young produced. Over this period numerous specimens of these birds have been shown to contain residues of dieldrin, heptachlor epoxide, or of DDT or its metabolites in amounts which support the view that such birds are especially liable to accumulate residues in their bodies. On a number of occasions, the residues of dieldrin were of the same order as those found in bodies—albeit of different species—which have been experimentally killed with the chemical. After examining this information, together with similar and relevant information from North America, we accept that the use of certain of these

pesticides has probably been a major factor in the recent decline of some British birds of prey.

99. Unfortunately we do not know precisely which uses of these pesticides have contributed mostly to the residues found, but an important determining property of these chemicals appears to be their persistence in the bodies of the prey species and their build up in the predators.

100. Similarly the information so far available in Britain concerning fish-eating species of birds is anything but reassuring. Residues have been found in the bodies of herons and their eggs and, in a few cases involving dieldrin, the amounts could have been lethal. Residues, almost certainly of some biological significance, have also been found in certain other fish-eating species. These birds are likely to have obtained the pesticides only from the fish on which they feed and it seems relevant that residues, although fairly small in amount, have been found in fish dropped by herons near to their nests. Recent work in Scotland has also revealed the presence of residues in fish taken from waters previously thought to be free from these pesticides.

Use in Gardens

101. We have found no evidence to suggest that the populations of any of our garden birds have been affected by the use of these pesticides. Moreover, insofar as any individual birds have been affected, there is very little information which specifically shows that the use of pesticides in gardens was responsible. Only a few of the birds and eggs which have been found to contain residues were taken from gardens: one or two were from parks and similar areas in large towns, but as the total amounts of the insecticides used in gardens are much smaller than those used in agriculture, public health, etc., many of the residues may have come from sources other than gardens.

102. Although there is no evidence of their populations being materially affected, birds are particularly numerous in gardens and it would be wrong to conclude that no individual birds have been affected. Indeed, the finding of residues of dieldrin, aldrin and of DDT in some slugs and worms from treated soils in gardens suggests how certain of these pesticides may find their way into birds from use in gardens.

Summary

103. Until there were voluntary restrictions on their use, large numbers of deaths of seed-eating birds in the spring followed the use of seed dressings containing aldrin, dieldrin and heptachlor and, at the same time, there were consequential deaths in predatory mammalian and avian species. Notwithstanding the restrictions, residues of certain of the pesticides are still widely distributed among wildlife and are not confined to the areas where pesticides are widely used.

104. The evidence of the decline of populations of certain predatory birds, combined with data on residues of dieldrin, and to some extent of DDT, are sufficiently convincing to conclude that such species are at risk, as also are certain aquatic birds. These pesticides are probably a major factor in the recent decline of some British birds of prey. There is insufficient evidence to suggest that the populations of other species have been affected either in gardens or in the countryside generally.

105. There is no evidence specifically to show that formulations of these pesticides used in gardens were the sources of residues found in birds or eggs. From data on residues found in worms and slugs, however, there is evidence that these invertebrates may pick up the pesticides and be a source of danger to birds feeding on them.

106. Although the residues found in many of the eggs examined are very small, there is evidence of these residues occurring in widely separated parts of the country. In some instances these residues may well have had an adverse effect on the viability of the eggs, but there is little experimental evidence on which to assess the significance of given residues in eggs.

107. The accumulative contamination of an environment by persistent chemicals from all sources is a factor which must be considered in any future recommendations for the safe use of these pesticides. Where persistence is essential for crop protection, the pesticides used should be no more persistent than is necessary, and should be of the lowest possible toxicity to other species.

VI. THE PROBLEM OF INSECT RESISTANCE, PARTICULARLY IN RELATION TO PERSISTENT ORGANOCHLORINE PESTICIDES

108. Resistance first came to public attention when insect pests, particularly those of public health importance, ceased to be controlled by DDT. Today, pesticides of most chemical groups fail to control some pest species against which they were once effective. Throughout the world about one hundred and thirty-five species of insects or ticks of medical, veterinary or agricultural importance (sixty-five being plant-feeding arthropods) now show field resistance to one or more pesticides. At present the situation is probably more serious in the public health than in the agricultural field.

109. Variations in susceptibility to a pesticide occur both within a species and within a population, the use of a pesticide acting as a powerful sieve for concentrating resistant mutants that were present in low frequencies in the original population. Resistance is not confined to chemical pesticides, for resistance to *Bacillus thuringiensis* has already been reported.

110. Enzymic detoxication is one factor of resistance, and this has been turned to advantage in the case of trichlorphon which is dehydrochlorinated to give dichlorvos, a more insecticidal material. Pests able to tolerate one chemical can often tolerate another, chemically similar, where the same detoxication mechanism operates. Cross-resistance is, however, not limited to pesticides of similar chemical structure, and resistance to some organophosphorus compounds confers cross-resistance to some organochlorine compounds, although the converse does not occur.

111. Only very few pests of agricultural importance in Great Britain exhibit resistance as yet. Resistance by cabbage root fly to aldrin, by fruit tree red spider mite to chlorbenside, chlorfenson and some organophosphorus

compounds, and by glasshouse red spider mite to azobenzene and possibly to dicofol and some organophosphorus compounds, has been reported.

112. Only two important instances of resistance to organochlorine pesticides in the field of food storage practice are known in Great Britain. The German cockroach has, in some areas, developed resistance to dieldrin, whereas the Oriental cockroach has shown no such resistance. Resistance, to DDT especially, has been met amongst some flies, the most important being the house-fly. At present it is largely confined to particular long-term infestations such as those on rubbish tips, and in most cases DDT is still the pesticide of choice.

113. Some stored product insects abroad, particularly in tropical conditions, have acquired resistance to some organochlorine and organophosphorus pesticides. The carriage of insects on food commodities in international trade could mean such insects becoming established in this country.

114. Overseas, the problem of resistance in agricultural pests is more acute. In Australia the cattle tick is resistant to DDT and BHC, and the sheep maggot fly to dieldrin. In both Europe and the U.S.A. the Colorado beetle is resistant to DDT, whilst the codling moth is resistant to DDT in New South Wales, Australia and both the East and West coast fruit growing areas of the U.S.A. The carrot fly is resistant to aldrin, chlordane and heptachlor in the U.S.A. and the Netherlands. Furthermore, the widespread use of a single pesticide to control many pests can lead to a rapid build up of resistance to that pesticide by those pests. Thus, in the U.S.A. parathion has been the most widely used organophosphorus pesticide and sixteen out of eighteen pests on which it has been used now show resistance.

115. Techniques for overcoming resistance have so far been largely empirical. This has often led to resistance appearing towards the substitute and the process has had to be repeated. The latest approach is the rotational use of pesticides from different chemical groups in such a way that each gives economic control; pest survivors being exposed at the next application to an unrelated chemical. By this means it is hoped that resistance to any one product is deferred, if not prevented.

116. It seems likely that persistent compounds are more likely to evoke resistance, or to evoke it more quickly, than non-persistent ones. Nevertheless it would seem unwise to reduce the potential reserve of insecticides by banning some materials completely.

VII. DISCUSSION

117. The organochlorine pesticides constitute one of the more important groups of pesticides available for pest and disease control, and we have studied the effects and possible hazards of specific members of this group on many occasions in recent years. Detailed recommendations for safe use in agriculture and food storage have been worked out for some of these pesticides

under the voluntary Pesticides Safety Precautions Scheme, and a number of products containing them have also been examined and approved for biological efficiency under the Agricultural Chemicals Approval Scheme.

118. When we were asked to undertake a general review of the risks arising from the use of the more persistent ones, certain new evidence about their effects and possible dangers had been becoming available through work undertaken by Government Departments and other agencies, research bodies and voluntary organisations. Some of this work was set in motion as a result of the Sanders Research Study Group Report on the use of toxic chemicals in agriculture and food storage, which in 1961 recommended various lines of further research.

119. The new evidence, which is set out in the foregoing sections of this Report, has advanced our scientific knowledge of these pesticides but, before drawing conclusions from it which may affect their future use, we feel bound to point out that there remain many important gaps in our knowledge and understanding. For example, the surveys of residues in food undertaken by our Residues Panel (paragraphs 59–64 and Appendix F) have shown dieldrin, DDT or BHC to be present in some of a number of imported and home-produced foodstuffs. While there is analytical evidence that the samples in question contain these residues, we have no certain knowledge, except for dieldrin in potatoes and home-produced mutton kidney fat, how the residues got there; nor do we know their precise toxicological significance in the national diet, or in the diet of particular classes of consumers. Again, although a limited survey in the United Kingdom of human body fat has shown the presence of DDT at an average level somewhat less than that in the United States, and a very low level of dieldrin (paragraphs 78–80), neither the sources of these deposits, nor the relative importance of different sources, have been fully determined. To date there is no evidence that these deposits do any harm.

120. So far as wild life is concerned, there is a good deal of evidence to show that the bodies of many birds of different species, and the eggs of some of them, contain small residues of organochlorine pesticides, and it is probable that in certain cases these pesticides were the cause of death. Knowledge is lacking, however, of the significance of different residue levels and of the amounts of the different pesticides needed to kill birds of different species other than pheasants, and we do not know what ill-effects, if any, are caused by non-lethal residues. Similarly there is no evidence on the proportion of birds adversely affected by pesticide residues, or on the significance of pesticides in relation to other causes of mortality.

121. More information on all these matters, and others affecting decisions on the agreed uses of pesticides in agriculture and food storage, will become available as research and investigation make further progress. Meanwhile, any recommendations we may make concerning the safe use of persistent organochlorine pesticides must continue to be based to some extent on reasoned inferences drawn in part from circumstantial evidence. When knowledge is incomplete, a cautious approach is clearly necessary.

122. Having considered the various uses of these organochlorine pesticides in agriculture and food storage which are described in paragraphs 12–58, our

general view is that there is no evidence that any of them is presenting any serious immediate hazard to human beings. So far as wild life is concerned, there is circumstantial evidence that some populations of predatory birds have suffered and there have been some deaths of other birds, but there is no evidence to show that the latter have recently been on a substantial scale.

123. On the other hand, it is a matter for concern that traces of some of the organochlorine compounds are being found in so many situations, whether or not it can be proved that they are doing serious harm. Small accumulations and residues in human bodies, human food, wild birds, fish, soil and some of the creatures which live in it, and water, suggest a widespread contamination of living things and their environment. The precise extent and degree of this contamination, the sources of it and the relative importance of each source are, however, not known with any accuracy. They probably include uses which are outside the scope of our remit. The root cause of this contamination is the unusual persistence of some of these pesticides, which retain their biologically active form in the environment over quite long periods. When they have done their job of controlling particular pests or diseases, by application to animals, plants or the soil, they do not degrade into harmless substances as many other pesticides do, but retain their toxic properties and find their way into situations where they accumulate, are unwelcome and may, in sufficient concentration, do harm.

124. From the pest and disease control point of view, a good degree of persistence is, of course, necessary in a pesticide where protection over a period is required. It would be wrong, therefore, to condemn persistence out of hand. But the use of too persistent pesticides could result in increased resistance building up in the pests we are trying to control. These and other effects should be watched, and a curb applied to the use of persistent pesticides before the side effects get out of hand.

125. In the case of the persistent organochlorine pesticides, the right course in the general public interest in our view is to find ways in which any further substantial increase of contamination in Great Britain by the more toxic of them can be avoided and the level of contamination if possible reduced. For this purpose it is necessary to consider what contribution is being made to the present situation by each of these pesticides in its various uses and to eliminate, reduce or set a term to any use for which a strong case cannot be made out. Against this general background, it is necessary to have regard on the one hand to any evidence which suggests that there may be particular hazards directly attributable to a present use, and on the other to any adverse effects on human health, food storage protection, and food production or other essential activities if an undoubtedly useful pesticide should no longer be available. We must consider what less persistent and less toxic pesticides are or may become available, and take account of other possible pest control methods, of problems of insect resistance and, in the case of veterinary preparations, of the effects on animals of continued exposure to pests.

126. We recognise that this general approach to the problem has led to our recommending restrictions on the use of certain pesticides in Great Britain which, on the basis of proved hazards arising from their use considered in isolation, it might not be easy to justify. Taking the overall view, however,

we think this must be accepted and the conclusions which follow and the recommendations which appear at the end of this report reflect our view that the contamination of the environment should be contained. While the evidence does not appear to us such as to call for restrictions to be imposed as a matter of great urgency, we think that a start should be made as soon as possible.

127. We stress that our views in this Report, as always, are based purely on the situation as we see it in Great Britain, and that although some of the risks apparent to us must apply in other countries, the economic and other factors are usually quite different and our recommendations may have no relevance there. We have been aware throughout that formulations of the pesticides under review contribute to the export trade of this country, and that many Commonwealth and emergent countries pay particular heed to the recommendations for the safe use of chemicals used in agriculture, which Departments make periodically.

128. We have noted that many of these persistent organochlorine pesticides have played, and still play, a vital part in public health schemes here and, particularly, abroad where the immediate gains from their use have often far outweighed the potential hazards to man or wild life. We have noted also that many persistent organochlorine pesticides are used highly advantageously in special circumstances, without any evident risk to human beings or wild life.

VIII. CONCLUSIONS

129. We have attempted to weigh in the balance the risks and benefits from the use of the persistent organochlorine pesticides. In forming our conclusions we have recognised the need:

(a) to avoid harmful or undesirable residues in food;
(b) to take account of the hazards to wild life;
(c) to take account of the needs of the agricultural and food storage industries;
(d) to ensure that effective pesticides will be available for control purposes, and in sufficient variety to safeguard against problems of insect resistance.

130. On grounds of human hazards, there is in our view insufficient evidence at present to justify a complete ban on any of the pesticides we have reviewed. There is, for instance, no basis for statements that these persistent organochlorine pesticides are severe liver poisons; nor is there any proof that DDT causes any injury while stored in the fat of human beings or animals. Similarly, DDT and dieldrin cannot be condemned as presenting a carcinogenic hazard to man. The limited evidence available shows that, of the residues found in food, the maximum dieldrin levels were obtained only in isolated cases and under conditions which are seldom likely to arise. Nevertheless, we consider that these levels of dieldrin residues are undesirable and the evidence justifies a partial restriction of its use. (Paras. 59–82)

131. On hazards to wild life, we are satisfied that the restrictions placed on the use of aldrin, dieldrin and heptachlor in cereal seed dressings in 1961 are serving their purpose, and have very greatly reduced the number of deaths of seed-eating birds through these chemicals. (Paras. 84–85)

132. We accept that some bird deaths, probably due to persistent organochlorine pesticides, may still be occurring which cannot be attributed to seed dressings. Although little is yet known about the toxicological significance of the residue levels found in birds, we agree that there is circumstantial evidence for the view that the decline in populations of certain predatory birds is related to the residues found in such species arising from the use of aldrin, dieldrin and heptachlor and, to some extent, DDT. We have received no evidence that the populations of other species have been affected by pesticides. (Paras. 87–89; 98)

133. Residues of persistent organochlorine pesticides found in birds' eggs are in most cases very small. Eggs containing these residues have, however, been found in widely separated parts of the country, and in a few cases the residues were substantial in amount. They may have an adverse effect on egg hatchability, but there is little experimental evidence on which to assess the significance of given residues. (Paras. 92–93)

134. No decline in the populations of garden birds came to our notice. Residues of organochlorine pesticides have been found in dead birds (old and very young) and eggs taken from gardens, but we have found no definite evidence to show that these residues were the result of the garden use of these pesticides. Nevertheless, although the garden use of these pesticides is relatively very small, discontinuance of the use of certain persistent organochlorine pesticides in gardens would be in accord with any general concept of reducing the total environmental contamination whenever satisfactory alternatives are available. (Paras. 101–102)

135. Although a degree of persistence is desirable for most pesticidal preparations, we take the view that the pesticides which are used should be no more persistent than is necessary for effective control; should be of the lowest possible toxicity to other species; and should not be used more widely than is necessary to achieve their purpose. We are firmly of the opinion that the present accumulative contamination of the environment by the more persistent organochlorine pesticides should be curtailed. Having reached this conclusion, we have sought an order of possible priorities by which their total usage in agriculture, horticulture and food storage practice could be reduced without serious set-back to pest control. (Paras. 123–124)

136. Aldrinated fertilizers are often applied annually as a form of insurance—this being an economical way of combating wireworm in potatoes at the same time as the farmer applies fertilizer. Such annual dosage is quite unnecessary for adequate pest control, and the availability of aldrin in fertilizer encourages the farmer to put aldrin on his land more often than is needed. For these reasons we are firmly of the opinion that the use of aldrin in fertilizer mixtures should be discontinued. (Paras. 64; 95 and Appendix E)

137. Provided BHC, DDT and certain carbamate and organophosphorus pesticides are still available, the use of aldrin and dieldrin dips and sprays for

sheep should be discontinued. This would involve some increased shepherding and labour costs (more than one dipping or spraying per year would become necessary in some parts of the country), less complete protection and perhaps a rise in economic loss from disease. (Paras. 57–58)

138. Aldrin is rapidly converted to dieldrin in the animal body and in the soil, and it is not possible to consider them separately. They have proved very useful in recent years in agriculture and horticulture, but we do not regard them as irreplaceable for many of their present uses. Nevertheless, it would be of considerable advantage if they could be available, to the professional grower only, for the next three years for use against wheat bulb fly up to the end of December; on rubbed and graded sugar beet seed; against wireworm in potatoes; and against cabbage root fly and narcissus bulb fly, since no effective economic alternatives exist at present. This period should provide the interval needed to seek suitable alternatives, with a view to discontinuance of the use of aldrin and dieldrin. (Appendix E)

139. Similarly in food storage practice, it would be an advantage to retain dieldrin for three years for the control of cockroaches and tropical species of ants. But dieldrin does not appear to be essential for other food storage uses. (Paras. 34–37)

140. Heptachlor is at present used only as a seed dressing for winter-sown cereals and sugar beet. If dieldrin continues to be permitted for these uses, the same concession must be given to heptachlor.

141. DDT and BHC have been in wide and extensive use in Great Britain for nearly 20 years. At first nothing occurred to suggest that their current use in Great Britain was harmful to man or wild life populations. Definite evidence of these chemicals being widely present as residues became available only with the advent of more sensitive analytical procedures. Even now, on the evidence available to us, we consider it unnecessary to place any restrictions at present on DDT and the much less persistent and less harmful BHC (including gamma-BHC). Indeed, their continued availability is essential if our proposals for aldrin and dieldrin are accepted. At the same time, we hope that efforts will be made to find equally effective, but less persistent, pesticides to replace the more persistent DDT.

142. We have not found it possible to pin-point the major sources of these pesticides occurring in human food, human fat and in wild life. This is because of the diverse uses which they have in agriculture, horticulture, food storage, forestry, shops, industrial premises and processes, public health and in the home, some of which are outside our terms of reference. In particular, dieldrin is used in wood preservation and moth-proofing both as an industrial process and in the home. Our information is that the quantities of dieldrin used industrially for these purposes exceed the total amount used in food storage practice. In any attempt to reduce the environmental contamination by persistent organochlorine pesticides, we consider there is a need for the Government to study the hazards possibly arising from the use of organochlorine pesticides other than in agriculture, horticulture, home gardens and food storage (such as wood-preserving, moth-proofing and in the home), and the contribution these uses might make to the contamination of the environment. (Paras. 9; 66)

143. The accumulative contamination of an environment by persistent pesticides from all sources is a factor which should in future be given greater weight by all concerned in proposals for the safe use of such chemicals.

144. Finally, we accept that some of our recommendations, if they are implemented, may lead to increased costs to the industries concerned. From such information as was available to us, it appeared that these increased costs would not be oppressive. There may also be an effect on the pesticide export trade, but on this we had no information on which to base a quantitative opinion.

145. *Endrin, endosulfan, chlordane, toxaphene and "Rhothane"*
We have been unable to complete our review of these pesticides in the time available, but we do not expect that any conclusions we may draw about them will affect our present proposals. A supplementary report covering these five pesticides will be submitted as soon as possible.

IX. RECOMMENDATIONS

146. We recommend that:

1. the use of aldrin and dieldrin in fertilizer mixtures should cease as soon as this can be arranged;
2. the use of aldrin and dieldrin in dips and sprays for sheep should cease as soon as this can be arranged;
3. (a) seed dressings containing aldrin, dieldrin and heptachlor may continue to be used, but only on (i) winter sown wheat (up to the end of December) where there is a real danger of attack from wheat bulb fly, and (ii) on rubbed and graded sugar beet seed for precision drilling;
   (b) aldrin and dieldrin may be available for commercial use only (i) against wireworm in potatoes, (ii) to control cabbage root fly and (iii) to control narcissus bulb fly;
   (c) dieldrin may be available to control cockroaches and tropical species of ants;
4. all other current uses of aldrin, dieldrin and heptachlor in agriculture, horticulture, home gardens and food storage practice should cease as soon as this can be arranged;
5. the uses listed in recommendations 3(a), (b) and (c) above should be reviewed at the end of three years with a view to their discontinuance;
6. no restrictions should be placed on the current uses of DDT in agriculture, horticulture, home gardens and food storage practice, but its use should be reviewed at the end of three years;
7. no restrictions should be placed on the current uses of BHC (including gamma-BHC) in agriculture, horticulture, home gardens and food storage practice;
8. the hazards possibly arising from the use of organochlorine pesticides for purposes other than in agriculture, horticulture, home gardens and food storage, including any contribution which these uses might make to

the general environmental contamination by organochlorine pesticides, should be studied without delay;

9. governmental and other bodies should intensify their efforts to encourage by education and advice the use of the less persistent pesticides, and to encourage economy in the use of persistent organochlorine pesticides where these may continue to be used.

147. In making these recommendations, we recognise that, if they are implemented, there might be a temporary increase in the use of DDT. We are confident that the pesticide industry will do its utmost to produce less persistent alternatives to aldrin, dieldrin, heptachlor and DDT.

148. None of our recommendations for restriction should apply to research workers who might need to use these pesticides as standards in developing new pesticides.

X. ACKNOWLEDGMENTS

149. We thank those individuals and organisations who submitted evidence to us.

150. We wish to record our indebtedness to our Scientific Subcommittee under the Chairmanship of Mr. W. C. Moore; to its joint technical secretariat; and, in particular, to Mr. A. H. Strickland of the Plant Pathology Laboratory who prepared the extremely valuable paper on usage which is reproduced at Appendix E to our report. We also acknowledge the great help given to us by the secretariat of the Advisory Committee in the final drafting of the report.

Signed: J. W. Cook,
Chairman

APPENDIX A
(PART I)

Membership of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage

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APPENDIX A

(PART II)

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Note: Dr. I. Thomas, M.Sc., Ph.D., F.I. Biol. (Director of the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food, and Chairman of the Wild Life Panel of the Scientific Subcommittee) was co-opted to the Subcommittee for the purpose of the review.

APPENDIX A

(PART III)

Membership of the Veterinary Subcommittee

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Secretary

S. F. M. Davies, Esq., B.A., B.Sc., M.R.C.V.S., Central Veterinary Laboratory, Ministry of Agriculture, Fisheries and Food

* Not appointed until after the completion of this Report.

APPENDIX B

Organisations and Individuals who submitted Evidence

Association of British Manufacturers of Agricultural Chemicals
Baywood Chemicals Limited
Boots Pure Drug Company Limited
British Veterinary Association
Dr. C. M. Fenn
Food Manufacturers' Federation Incorporated
Industrial Pest Control Association
Joint British Trust for Ornithology/Royal Society for the Protection of Birds Committee on Toxic Chemicals, in collaboration with the Game Research Association
National Farmers' Union
National Union of Agricultural Workers
Nature Conservancy
Plant Protection Limited
Shell Chemical Company Limited

In addition, we received from Sir Harold Sanders [Chief Scientific Adviser (Agriculture) to the Minister of Agriculture, Fisheries and Food] a confidential summary of manufacturers' replies to a questionnaire sent to members of the Association of British Manufacturers of Agricultural Chemicals on tonnages of active ingredients formulated for sale in the United Kingdom.

APPENDIX C

Persistent Organochlorine Pesticides and their principal metabolites of interest

(Where appropriate, names conform witb British Standard 1831 : 1961)

Aldrin. Technical aldrin contains approximately 95 per cent of the compound HHDN, which is the principal active insecticidal ingredient. Residues in plants, soils and animal tissue are converted into HEOD (see dieldrin) by epoxidation and this is the stable residue: the rate of conversion appears to be greatest in animal tissue. For this reason it is convenient to consider aldrin and dieldrin residues together as dieldrin.

BHC. BHC (benzene hexachloride) exists in a number of isomeric forms of which gamma-BHC is the principal insecticidal compound. The gamma-isomer is available as the pure isomer (lindane), or as technical grades of BHC containing various proportions of gamma-BHC from about 13 per cent upwards. It is rather less persistent than some other of the organochlorine pesticides, beta-BHC being the most persistent of the principal BHC isomers.

Chlordane. Technical chlordane is a mixture of a number of compounds the principal of which are the isomers alpha- and beta-chlordane; these together account for from 60 to 75 per cent of the technical material.

DDE. See DDT.

DDT. The principal active insecticidal ingredient of technical DDT is the isomer pp'-DDT (approximately 70 per cent), other isomers including op'-DDT; a small proportion of TDE isomers is also present. Residues in animal tissue are slowly dehydrochlorinated to pp'-DDE and this compound may account for as much as 70 per cent of the pp'-DDT originally present in the animal organism. DDT, DDE and TDE and their individual isomers may be determined separately in residue analysis but it is sometimes convenient to express the overall results as a single "total DDT equivalent" figure.

Dieldrin. Technical dieldrin contains approximately 85 per cent of the compound HEOD, which is the principal active insecticidal ingredient. Residues of HEOD in plants, soils and animal tissue are relatively stable.

Endosulfan. Technical endosulfan (also known as "Thiodan") consists of two principal isomers, endosulfan A and endosulfan B; the former predominates in the ratio of about 4:1 but the latter is the more persistent and so may occasionally predominate in endosulfan residues. Both isomers are slowly converted into the same relatively inactive compound, endosulfan alcohol.

Endrin. Endrin is similar to HEOD (see dieldrin) both chemically and toxicologically but although they have the same formula they are quite distinct substances and may be distinguished in analysis and in other ways. The basic difference between HEOD and the active ingredient of endrin lies in the internal spacial configuration of otherwise identical molecules. (Aldrin on epoxidation always gives rise to dieldrin, not endrin).

Heptachlor. Technical heptachlor contains 70 to 75 per cent of the principal active insecticidal ingredient heptachlor. Like aldrin, it epoxidises in plants, soil and animal tissue to a compound, heptachlor epoxide, which is analogous to HEOD (dieldrin) in chemical structure.

Heptachlor Epoxide. See heptachlor.

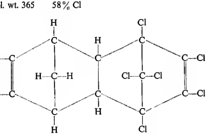
"*Rhothane*". "Rhothane" (also known as DDD or TDE) is chemically similar to DDT, the technical material consisting mainly of pp'-TDE. As indicated under DDT, some TDE residues may be derived from the small TDE content of technical DDT; in addition, however, there is some evidence that TDE residues may also arise by the reduction of DDE residues, themselves derived from DDT by dehydrochlorination. At the same time, TDE residues may arise from the direct use of TDE. Another compound, dehydrochlorinated pp'-TDE, is also found; this has the same relationship to pp'-TDE that pp'-DDE has to pp'-DDT.

Toxaphene. Toxaphene is prepared by chlorinating technical camphene to a chlorine content of about 68% (corresponding to "octachlorocamphene") and is a mixture of several individual compounds.

Aldrin (HHDN)

1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-*exo*-1,4-*endo*-5,8-dimethanonaphthalene.

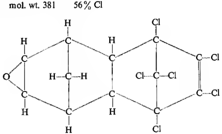
$C_{12}H_8Cl_6$ mol. wt. 365 58% Cl



Dieldrin (HEOD)

1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-*exo*-1,4-*endo*-5,8-dimethanonaphthalene.

$C_{12}H_8Cl_6O$ mol. wt. 381 56% Cl



Endrin

1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-*exo*-1,4-*exo*-5,8-dimethanonaphthalene.

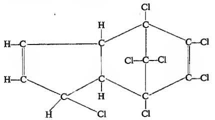
$C_{12}H_8Cl_6O$ mol. wt. 381 56% Cl

Chemical formula: same as for dieldrin.

Heptachlor

1,4,5,6,7,10,10-heptachloro-4,7,8,9-tetrahydro-4,7-methyleneindene

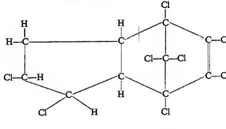
$C_{10}H_5Cl_7$ mol. wt. 373·5 67% Cl



Chlordane

1,2,4,5,6,7,10,10-octachloro-4,7,8,9-tetrahydro-4,7 methyleneindane

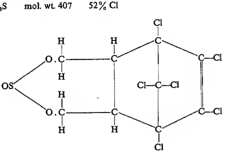
$C_{10}H_6Cl_8$ mol. wt. 410 69% Cl



Endosulfan

6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzo [e] dioxathiepin 3-oxide

$C_9H_6Cl_6O_3S$ mol. wt. 407 52% Cl



Toxaphene

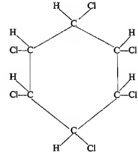
Chlorinated camphenes. "Octachlorocamphene" mixed compounds

$C_{10}H_{10}Cl_8$ mol. wt. approx. 414 67–69% Cl

Gamma-BHC

gamma-1,2,3,4,5,6-hexachlorocyclohexane

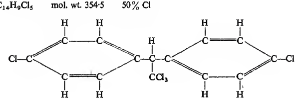
$C_6H_6Cl_6$ mol. wt. 291 73% Cl



pp'-DDT

1,1,1-trichloro-2,2-di-(4-chlorophenyl)ethane

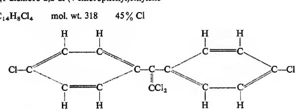
$C_{14}H_9Cl_5$ mol. wt. 354·5 50% Cl



pp'-DDE

1,1-dichloro-2,2-di-(4-chlorophenyl)ethylene

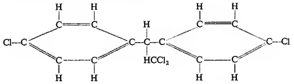
$C_{14}H_8Cl_4$ mol. wt. 318 45% Cl



"*Rhothane*" (TDE or DDD)

1,1-dichloro-2,2-di-(4-chlorophenyl)ethane

$C_{14}H_{10}Cl_4$ mol. wt. 320 44% Cl



APPENDIX D
(Part I)

Agricultural and Horticultural Uses of Organochlorine Pesticides Against Specified Pests

Pest	Aldrin spray/dust	Aldrin seed dressing	Aldrin fertiliser	Dieldrin spray/dust	Dieldrin seed dressing	Heptachlor seed dressing	DDT spray/dust	BHC spray/dust	BHC seed dressing	Endrin	Endosulfan	Chlordane	Toxaphene	"Rhothane"	Others
Aphids							X		X	X					most O–P compounds; nicotine
Apple sawfly								X		X					dimetboate; malathion; nicotine; pbosphamidon
Apple sucker								X							dimethoate; malathion; mecarbam; nicotine
Bean seed fly	X				X			N.A.	X						certain O–P compounds (N.A.)
Black currant leaf curling midge							X								
Black currant gall mite										X	X				lime sulphur
Blossom beetles				X			X	X							malathion
Blossom weevils				X			X							X	
Bulb scale mite										X					
Cabbage caterpillars							X								lead arsenate (N.A.); mevinphos
Cabbage rootfly	X			X				X							diazinon (N.A.); mercuric chloride (N.A.); calomel (partial control)
Capsids							X	X						X	diazinon; nicotine
Carrot fly	X			X	X				X						diazinon (N.A.); disulfoton (N.A.)

Agricultural and Horticultural Uses of Organochlorine Pesticides Against Specified Pests—continued

Pest	*Aldrin spray/ dust*	*Aldrin seed dressing*	*Aldrin fertiliser*	*Dieldrin spray/ dust*	*Dieldrin seed dressing*	*Heptachlor seed dressing*	*DDT spray/ dust*	*BHC spray/ dust*	*BHC seed dressing*	*Endrin*	*Endo-sulfan*	*Chlordane*	*Toxa-phene*	*"Rhothane"*	*Others*
Cecids . .							X	X							diazinon; malathion
Chafers . .	X			X				N.A.							
Clover weevils .				X			X								
Codling moth .							X								azinphos-methyl; carbaryl; lead arsenate; malathion; phosphamidon
Cutworms . .	X			X			X								paris green (N.A.)
Cyclamen mite .										X					
Earwigs . .				X			X	X						X	
Earthworms in turf												N.A.	N.A.		lead arsenate; mercuric chloride (N.A.); mowrah meal
Flea beetles .				X	X		X	X	X						
Frit fly . .				X			X								
Large narcissus fly	X			X				X							
Leafhoppers .							X								demeton-methyl; dimethoate; malathion
Leatherjackets .	X			X			X	X							lead arsenate; paris green (N.A.)
Lucerne weevil .				X			X								
Mangold fly .				X			X								trichlorphon; dimethoate and, to a lesser degree, certain other O–P compounds used as aphicides on sugar beet
Millipedes . .	X							X							
Mustard beetle .				X			X								malathion

Pest	Aldrin spray/dust	Aldrin seed dressing	Aldrin fertiliser	Dieldrin spray/dust	Dieldrin seed dressing	Heptachlor seed dressing	DDT spray/dust	BHC spray/dust	BHC seed dressing	Endrin	Endosulfan	Chlordane	Toxaphene	"Rhothane"	Others
Onion fly					X				X						calomel (partial control); certain O–P compounds (N.A.)
Pea and bean weevil				X			X	X							
Pear sucker								X							most O–P compounds used on fruit; nicotine
Raspberry beetle							X								derris; malathion
Raspberry cane midge								X							
Strawberry seed beetle	X														
Symphylids	X			X				X							diazinon; parathion
Thrips				X			X	X						X	diazinon; malathion; nicotine; parathion
Tortrix moth caterpillars							X			X				X	azinphos-methyl; carbaryl; lead arsenate
Turnip gall weevil	X														
Vine weevils	X						X	X							lead arsenate (N.A.)
Wheat bulb fly		X			X	X			X						
Winter moth caterpillars							X			X				X	carbaryl; lead arsenate
Wireworms	X		N.A.	X		X (beet)		X (not potatoes)	X						

Notes: 1. "N.A." denotes *not* approved for efficiency under the Agricultural Chemicals Approval Scheme.
2. "O–P" denotes "organophosphorus".

APPENDIX D

(Part II)

Persistent Organochlorine Pesticides "Approved" (under the Agricultural Chemicals Approval Scheme) for use against Specified Pests in Home Gardens

Pest	*Aldrin*	*Dieldrin*	*DDT*	*BHC*	*Approved alternatives*
Ants	X			X	
Aphids			X	X	malathion; nicotine
Apple sucker			X	X	malathion
Bean seed fly	X				
Cabbage root fly	X	X		X	
Capsids			X	X	malathion
Carrot fly	X	X			
Caterpillars			X		derris; malathion
Cutworms	X		X		
Earwigs	X	X	X	X	
Flea beetles	X	X	X	X	derris
Leaf hoppers			X	X	malathion; pyrethrum/derris
Leafminers				X	malathion; nicotine
Leatherjackets	X	X	X	X	
Midges			X		
Millipedes	X		X	X	
Mushroom flies			X	X	malathion
Onion fly	X			X	
Raspberry beetle			X		derris; malathion
Sawflies			X	X	derris; nicotine
Springtails			X	X	
Thrips		X	X	X	derris; malathion; nicotine
Wasps		X	X		derris
Weevils	X	X	X	X	
Whiteflies			X		malathion; pyrethrum/derris
Wireworms	X			X	
Woodlice			X	X	

N.B.—Chlordane, endrin, endosulfan, heptachlor, "Rhothane" and toxaphene - no approval for efficiency granted for home garden use.

APPENDIX E

Persistent Organochlorine Pesticide Usage on Crops in England and Wales

(Prepared by Mr. A. H. Strickland, Plant Pathology Laboratory, Harpenden, at the request of the Scientific Subcommittee)

This paper is in three parts: 1. Aldrin and Dieldrin Usage; 2. A Note on Chlordane, Endosulfan, Endrin, Heptachlor and "Rhothane"; and 3. Usage of DDT and BHC. A uniform presentation has been adopted throughout.

PART 1: ALDRIN AND DIELDRIN USAGE

1.1. *Introduction.* Aldrin and dieldrin were first available in the United Kingdom for experimental use in 1952/53. Commercial scale field trials were done in 1953/54, and the materials were available to commercial growers in, and after, 1955. The following notes therefore apply to use on farm land over the past nine crop seasons.

1.1.1. *Aldrin/Dieldrin Conversion.* In various biological environments aldrin is readily converted, or epoxidized, to dieldrin, either directly or by a process of biological oxidation. This process can occur within treated plants, insects, and other animals, as well as by microbial action in the soil. Virtually all commercial formulations of aldrin contain small amounts of dieldrin, and the amount of dieldrin recoverable from plant or animal tissues, or soil, after treatment with aldrin is invariably greater than the initial concentration of dieldrin in the spray mix. About 35 per cent of the applied aldrin is converted sooner or later into dieldrin. Because of the difficulty of separating these two chemically similar compounds, and because they are similar toxicologically, they are considered together in the notes which follow.

1.1.2. *Persistence.* When a volatile material is applied to a crop some is lost into the atmosphere as spray drift or by volatilization from the plant or soil surface. Much will, however, land on the soil; and some which lands on the crop will end up in the soil when the unwanted plant material is ploughed in. Once an organochlorine insecticide has been incorporated into the soil it enters a sorbed, or colloidally bound, state and is only leached away to a trivial extent. Dieldrin is more persistent than aldrin, the soil-sorbed half-life varying from 6 months when massive amounts are applied to not less than 4 years for doses of 1–3 lb. per acre in some soils under English conditions. In the field incorporation of 2 lb. of dieldrin (or its aldrin equivalent) into a loam soil will give rise to a sorbed residue of 8–16 oz. 4–5 years later.

1.1.3. *Methods of Application and Dosages.* Aldrin is cheaper, and often more toxic to insects, than dieldrin. While methods of application are similar, dosages differ. The position can be summarised briefly:

Aldrin and Dieldrin Dosages (lb. active ingredient per acre) for Various Treatments

Material	*Fertiliser mixtures*	*Sprays and dusts*	*Drenches*	*Dips*	*Seed dressings*
Aldrin	1·0–4·0	1·5–3·0	0·4–2·0	0·3–1·8	0·1–0·8
Dieldrin . . .	(not used)	0·3–1·5	0·2–1·0	0·3–1·8	0·1–0·6

Note: Aldrin dosage in some fertiliser mixtures can be as high as 8–9 lb. active ingredient per acre.

The above are recommended dosages per application. A given crop may receive more than one application in the course of a season.

1.2. *The Usage Estimates.* Estimates of aldrin and dieldrin usage are not easy to obtain, and are even more difficult to interpret.

1.2.1. *Sources of Information.* The following have supplied information and data from which the usage estimates have been derived: The British Sugar Corporation (BSC); The Potato Marketing Board (PMB); The Pea Growers' Research Organisation (PGRO); The National Agricultural Advisory Service (NAAS); and the official Survey of Fertiliser Practice (SFP). Much information has also been supplied by colleagues at Rothamsted Experimental Station (RES), the National Vegetable Research Station (NVRS), East Malling Research Station (EMRS), and Plant Pathology Laboratory (PPL).

1.2.2. *The Nature of the Estimates.* The usage estimates have been obtained in four ways:

1.2.2.1. From statements made to BSC and PMB Field Staff in the course of annual inspections and sugar beet and potato crop surveys.

1.2.2.2. From the SFP, 1962 and 1963, and the RES Maincrop Potato Survey, 1963.

1.2.2.3. From replies to postal surveys done in recent years by the NAAS Eastern and East Midland Region Entomologists, by the PGRO, and by PPL.

1.2.2.4. From usage estimates made by District Advisory, Horticultural Advisory, and Specialist, Officers in the NAAS. District and Regional estimates have been interpreted in terms of the acreage of each crop grown; hence the final summations are not biased by cropping differences from one part of the country to another.

The estimates from these sources have been checked where possible against information on the amounts of insecticide sold for use in the U.K., and in some cases by NAAS officers against information supplied direct to them by local corn and agricultural merchants.

1.2.3. *The Accuracy of the Estimates.* The usage estimates vary in accuracy for three reasons:

1.2.3.1. *Tonnage Discrepancies.* Some firms import part or all of their active ingredients. In a few cases it has not been possible to relate acreages reported to have been treated with tonnages of materials used.

1.2.3.2. *Sample Bias.* Except in the case of BSC records (every sugar beet crop is visited, and data for the whole acreage are effectively free from error) the estimates are known to be affected to some extent by sample bias. The best example relates to the contrasted PMB and SFP estimates of aldrinated fertiliser usage on maincrop potatoes. The PMB estimate for 1962 is based on 1,923 growers who were visited and questioned. The final estimate was that 68,800 acres received aldrinated fertiliser in that year. The SFP estimate for 1962 was based on visits to 700 growers and the final estimate was that 51,700 acres received aldrinated fertiliser. A third estimate can be derived from information supplied to the Ministry by the Fertiliser Manufacturers' Association: that 37,000 tons of aldrinated fertiliser were formulated for use on potatoes in 1962 (and a further 3,000 tons for use on cereals). At an average application rate of 12 cwt of fertiliser per acre, this figure suggests that 62,000 acres may have been treated in 1962.

While it is believed that the table at para. 1.2.4. indicates the right order of magnitude of usage, it should be noted that sampling errors do not allow great precision to hc obtained.

1.2.3.3. *Human Fallibility.* In recent surveys in the Eastern Counties 1,351 growers were approached and 139 of them admitted to not knowing what insecticides they

had in fact used. A similar state of affairs was noted at PPL during the 1957 Strawberry Survey, the 1961 Soil Residue Survey, and in the small scale 1962 Potato Tuber Residue Survey. There were uncertainties, too, in respect of potato haulm defoliants in the 1963 RES Maincrop Potato Survey. The fallibility of growers' memories clearly imposes a limit on the accuracy which can be attained even in surveys which involve direct interrogation of individual farmers. The many brand names under which active ingredients are sold accounts for a further element of doubt in replies to survey questions. Apart from these points, there is a certain amount of mis-use which can be attributed to ignorance or, occasionally, to the press of circumstance. Recent examples include: the use of cereal seed dressings on potatoes; the use of aldrinated fertiliser for slug control; and the use of a cereal weedkiller to burn off potato haulm.

1.2.4. *Estimates of Acreages Treated.* The table below relates to those crops known to be treated with aldrin and dieldrin.

Acreages Grown, and Acreages Believed Treated, with Aldrin and Dieldrin, England and Wales, 1962/63.

Crop	*Acreage grown in England and Wales (to the nearest hundred)*	*Acreages believed treated with aldrin/dieldrin as:* *Aldrinated fertiliser*	*Sprays, dusts, and drenches*	*Dips and seed dressings*
Wheat	1,834,300	20,000	18,300	157,500
Barley	4,153,400	—	67,900	14,800
Oats	615,100	—	11,300	6,100
Maincrop potatoes	430,600	68,800	22,100	—
Sugar beet	408,400	—	—	204,200
Edible brassicae*	118,600	—	14,700	58,900
Carrots	31,300	—	25,900	4,600
Mustard	25,200	—	9,800	—
Strawberries	14,500	—	450	—
String beans†	13,500	—	100	6,400
Narcissus	7,700	—	—	630
Celery	5,800	—	600	—
Onions	5,300	—	—	100
Totals	7,663,700	88,800	171,150	453,230

Note: **Edible brassicae* = Cabbages, cauliflowers, broccoli, sprouts, kale, turnips and swedes for human consumption.
† *String beans* = Dwarf beans and scarlet runners.

These acreage estimates were obtained from information that a given area received at least one treatment in the year(s) in question. Thus, a carrot crop may have been drilled with dressed seed and subsequently sprayed with dieldrin: in such cases the acreage appears in the Spray and the Seed Dressing columns. Except where they are mutually exclusive, the acreages are not necessarily additive.

1.2.5. *The Areas Where Treatment is Applied.* Usage is not restricted to the main arable areas. To summarise the position, England and Wales have been arbitrarily divided into four sectors: *North.* The Northern and Yorkshire and Lancashire Advisory Regions; *East.* The East Midland, Eastern, and South-East (Wye) Advisory Regions; *South.* The South-East (Reading) and South-West (Bristol) and (Starcross) Advisory Regions: and *West.* The West Midland Region and the whole of Wales.

In preparing the table overleaf it has been assumed that the acreages are additive. This may have led to over-estimates in some areas in respect of wheat (some winter crops may receive seed dressings and a soil treatment against wheat bulb fly), brassicae, carrots and beans. Possible bias is, however, believed to be small.

Estimated Area Usage of Aldrin/Dieldrin in 1962/63: Acres Treated.

Crop	North	East	South	West
Wheat	52,800	123,200	7,600	12,200
Barley	31,400	25,100	22,000	4,200
Oats	10,200	2,500	1,100	3,600
Maincrop potatoes	26,500	34,800	12,300	17,300
Sugar beet	19,200	166,800	2,800	15,400
Edible brassicae.	4,800	46,700	10,900	11,200
Carrots	5,000	23,500	400	1,600
Mustard	900	8,900	—	—
Beans	40	6,500	—	—
Strawberries	1	400	30	20
Narcissus	80	—	550	2
Celery	350	250	—	—
Onions	100	—	—	—
Total acreage of qualified crops in each area	1,245,400	4,109,000	1,459,700	849,600

1.3. *The Pests for which Treatment is Applied.* The information in this section is set out in a crop-by-pest basis. It has proved impossible to prepare a coherent statement without anticipating some of the points made in greater detail in para. 1.6., and in Parts 2 and 3.

1.3.1. *Cereal Pests.* Wheat bulb fly; frit fly; wireworms, leatherjackets, and occasionally cutworms. Wheat bulb fly is dealt with in detail at para. 1.6.1., and for the present it suffices to say that virtually all of the dieldrin-dressed seed is of winter wheat sown in known wheat bulb fly areas: over 45,000 acres in Yorkshire, 60,000 acres in the Eastern Counties, and 37,000 acres in the East Midlands. About 10,000 acres of winter wheat are grown from dieldrin-dressed seed in the West Midlands, and 3,000 acres in the Northern Region. A further 56,000 acres of winter wheat is drilled with heptachlor-dressed seed (see para. 2.4.) in the Eastern Counties.

Only part of the cereal acreage which is sprayed or given direct soil treatment is treated because of wheat bulb fly. About 30,000 acres in the table at para. 1.2.4. relate to the wheat bulb fly areas. The remainder of the wheat acreage, and the whole of the treated barley and oat acreages, are treated because of frit fly (oats), wireworms, leather-jackets and (very occasionally) cutworms. One of the least important is frit fly, and probably not more than 6–7,000 acres of oats are treated annually in the North, the East and West Midland Regions, and Wales.

The major part of the sprayed/soil treated acreage relates to an estimated 68,000 acres of barley treated for wireworm and leatherjacket control. So far as wireworms are concerned, BHC seed dressings are generally adequate, and in practice much of the treatment is done for leatherjacket control in those Regions where this pest is troublesome; 2 per cent of the acreage in the Northern, Yorks. and Lancs., and East and West Midland Regions; and as much as 5 per cent of the cereal acreage in the South-West in recent years. In some districts (mainly in the South-East and South-West) BHC is widely used for leatherjacket control in crops following ploughed-out grassland. DDT and paris green are also in use for this purpose.

1.3.2. *Wireworm in Maincrop Potatoes.* The 91,000 acres of maincrop potatoes which received aldrin treatment against wireworm in 1962 relate to about 20 per cent of the crops grown. Usage is at a low level in the old arable Eastern County areas (virtually nil, for instance, in the Isle of Ely) where much of the National crop is grown. It is highest in Yorkshire, Shropshire, and the South-East, where wireworm damage has been trouble-some for many years. There is evidence that many growers in these old wireworm districts tend to apply aldrinated fertiliser as a routine insurance treatment regardless of need; the justification for this is discussed at para. 1.6.4.

1.3.3. *Sugar Beet Soil Pests.* In 1961 the BSC decided that henceforth all beet seed should be dressed with insecticide to protect the stand from damage by wireworms and

millipedes. Since then approximately 50 per cent of the seed sown annually has been dressed with dieldrin, and a further 35 per cent with heptachlor. In terms of active ingredient this usage is small: 1 lb. of heptachlor is sufficient to dress the seed for 25 acres.

1.3.4. *Treatment of Edible Brassicae.* Primarily for cabbage root fly control, though treatments are sometimes applied for flea beetle, cabbage stem weevil, and cabbage caterpillars including diamond back moth. Aldrin or dieldrin treatments appear to be applied more or less as a routine measure on many of the edible brassicae: mainly to summer and autumn cauliflowers, and summer, autumn and winter cabbages. In some areas slight damage is occasionally done to Brussels sprouts, and in the South-West swedes and turnips are damaged from time to time. Of the 118,600 acres of edible brassicae shown in the table at para. 1.2.4., 45,300 acres relate to the highly susceptible cauliflowers and cabbages, and 49,600 acres to Brussels sprouts. Although root fly is seldom a problem on sprouts, many growers appear to treat as a routine; in the relatively drier Eastern Counties about 11,000 of the 25,600 acre sprout crop is treated. In the wetter Evesham area, on the other hand, sprouts are less often treated. Stock-feed brassicae (kale, swedes, turnips) often receive protective treatment against flea beetle with BHC or DDT, but are seldom if ever affected by root fly seriously enough to justify chemical control.

1.3.5. *Carrots.* Virtually the whole of the maincrop areage is treated with dieldrin for carrot fly control, (para. 1.6.7.).

1.3.6. *Mustard.* The mustard crop of 25,000 acres is liable to damage from seed and pollen beetles. Mustard for green manure and stock-feed is not treated. Approximately 16,000 acres of Trowse and White mustards are grown for seed and the entire acreage is usually treated annually, but because the pests differ only the Trowse crop is treated with dieldrin. DDT is used on the White crop; but farmers who grow both types usually apply dieldrin to both. The mustard processors are now encouraging the production of a new, early maturing, White variety: Bixley. The trend, therefore, is away from Trowse mustard and use of dieldrin.

1.3.7. *Dwarf and Runner Beans.* Treatment is restricted to the control of bean seed fly which responds well to seed dressings: about 3 oz. active ingredient per acre. While generally distributed, this fly is only of sporadic importance. Some 3,800 acres of the Eastern County crop is drilled with dressed seed, and it is believed that the whole of the Kent acreage is so treated. Experimental work in Kent indicates that seed treatment can give good increases in seedling stand in the face of a severe seed fly attack: Untreated seed: 1; BHC dressed: 1·5; aldrin dressed: 1·8; plants per unit area.

1.3.8. *Strawberries.* Strawberry seed beetle is the only soft fruit pest for which aldrin is the best, and recommended, control. Small acreages (1–20) are treated annually in the North and West; but the pest is mainly important in the South-East, and about 10 per cent of the Kent crop of 2,900 acres is treated. Less than 100 of the Eastern County acreage of 7,400 are treated. About two-thirds of the strawberry growers use other organo-chlorine compounds for pest control.

1.3.9. *Narcissus.* Virtually the only use of aldrin and dieldrin is as a dip or soil treatment for large narcissus bulb fly control. This is essentially a pest in the South-West, and about 550 acres of bulbs are treated annually in this area. A further 80–100 acres of dipped bulbs are planted in Yorkshire and Lancashire. The fly is not a problem in the other bulb growing areas.

1.3.10. *Celery.* Carrot fly is a problem on celery in Lancashire, and about 60 per cent of the 640 acre crop is treated annually. There is little to choose between BHC and dieldrin for this purpose, and the move to aldrin and dieldrin has apparently arisen from taint fears.

1.3.11. *Onions.* Onion fly is sometimes troublesome in Yorkshire and Lancashire, and about half the acreage is set with dressed seed.

1.4. *Conclusions.* Some 500,000 acres of crops are treated annually with aldrin and/or dieldrin formulated as seed dressings and dips, about half being sugar beet. About 260,000 acres are treated annually with these materials in other formulations. It is not possible, on present knowledge, to discriminate between acreages receiving both kinds of treatment and acreages which only receive one kind.

It is clear that aldrin/dieldrin usage is greatest on cereals, sugar beet, potatoes, edible brassicae and carrots. The extent to which this usage is justified is discussed in sections 1.6. and 1.7.

1.5. *An Experimental Approach to Usage Problems.* In the 16 years since DDT and BHC have been widely available, and in the nine years since aldrin and dieldrin have been in use, a considerable amount of experimental work has been done with them on a commercial crop scale. Such trials are drilled, or set, on farms and are usually surrounded by a normal commercial crop of the kind under test. Yields are taken with care, and marketable produce (e.g., of carrots or cabbages) is recorded apart from gross yield, the latter usually containing a component too badly damaged for the retail market.

In addition to these experimental data, a good deal of information is available on the ecology of some of the major crop pests derived from research and investigational work done at Research Stations, routine monitoring of pest incidence done by NAAS officers, and surveys done by the PMB, BSC, SFP and NAAS.

1.5.1. *Sources of Information.* In the present context data have been examined relating to the three cereal pests: wheat bulb fly, wireworms, and leatherjackets; wireworm damage to potatoes; cabbage root fly; carrot fly; and mustard beetles. Enough reliable information is available on all but leatherjackets to allow realistic estimates to be made of the extent to which aldrin/dieldrin usage is necessary. Apart from the sources mentioned at paras. 1.2.1. and 1.2.2., the following published work has been drawn upon:

Cereals: Gough; Gough, Woods, Maskell and Towler; Maskell and Gair: (*Bull. Ent. Res.*, **48**, 1957; **52**, 1961);

Potatoes: Strickland, Bardner and Waines: (*Plant Pathology*, **10**, 1961);

Sugar Beet: Dunning: (*Chemistry and Industry*, **4**, 1962; *Plant Pathology*, **10**, 1961).

Brassicae: Wright: (Annual Reports of the National Vegetable Research Station, 1951–1960); (*Ann. appl. Biol.*, **40**, 1953); Moreton and Light; Light and Moreton; Moreton, Light and John: (*Plant Pathology*, **1**, 1952; **4**, 1955; **6**, 1957; **7**, 1958);

Carrots: Wright: (Annual Reports of the NVRS, 1950–1961); Brown; Thomas and Bevan; Shaw, Allan and Inkson; Shaw and McDonald: (*Plant Pathology*, **3**, 1954; **4**, 1955; **5**, 1956);

Mustard: Winfield: (*Ann. Appl. Biol.*, **49**, 1961; *Bull. Ent. Res.*, **52**, 1961).

Papers cited in the bibliographies of these articles have also been consulted.

1.5.2. *Procedure.* First, all available sources of information on pest incidence were investigated. The resulting estimates of 'Acreage Annually At Risk' attempted to pinpoint the localities where each pest is known to occur at population levels high enough to do economic damage. These estimates were then circulated to colleagues at PPL, RES, NVRS, EMRS, and in the NAAS, and modified where necessary before inclusion in the table at para. 1.7. below. For example, direct calculation of the acreage of winter wheat At Risk from wheat bulb fly was attempted from SFP data on the proportions of the winter wheat acreages in the known wheat bulb fly counties which followed bare fallows, potatoes, roots, and peas. This estimate indicated that a total of 380,000 acres of winter wheat might conceivably be badly damaged if *all* crops following these row crops and fallows were attacked in the 18 counties where the pest is known to be troublesome. However, wheat bulb fly is not uniformly distributed over the whole of all 18 counties, and the actual Acreage At Risk is thought to be about half that estimated: that is, 190,000 acres.

Secondly, all of the available field experimental data—including unpublished research results—relating to work with the organochlorines and other pesticides were tabulated alongside the relevant untreated plot data to see how effective the materials really are when results from a range of experimental sites and years are critically compared.

Thirdly, the amended estimates of Acreage At Risk have been used in conjunction with the field experimental results to estimate: (a) the likely annual loss if no control measures are taken; (b) the likely loss if control measures which do not involve aldrin, dieldrin or heptachlor are used; and (c) the likely benefit due to use of aldrin and dieldrin in preference to other materials or methods.

This approach may give somewhat exaggerated estimates of losses and benefits. This is because most field trials are done under conditions conducive to pest attack (e.g., by deliberate late drilling), and the untreated plot yields—used below as datum lines—may be on the low side in some cases.

Finally, all estimates have been consolidated in terms of Acreage Equivalents. It is felt that this convention gives a better picture of the overall position than could be obtained from estimates expressed in financial terms: variable production costs, wholesale prices, and the fact that some alternative chemicals have not yet been priced on the U.K. market, make it difficult to assess economic losses.

1.6. *Summary of Experimental Estimates of Yield Increases from Use of Aldrin and Dieldrin.* In each of the cases set out below a detailed analysis has been prepared and a summary only is included here.

1.6.1. *The Use of Seed Dressings against Wheat Bulb Fly.* Results from 26 field trials done in the Eastern and East Midland Regions over the period 1951–59 have been summarised and are shown in the table below. Attack on the untreated (organomercury seed dressing) plots was heavy enough to give, on average, spring larval populations at the ½-million per acre level. It is generally accepted that treatment is uneconomic at lower levels of larval survival.

Mean Yield (Cwt. of Grain at 85% d.m./acre) from all Untreated (Organomercury Seed Dressing) Plots, and Differences between Untreated Plots and the BHC and Dieldrin Plots.

Average yield from all untreated plots (26 trials)	*Increase in yield over untreated due to:*		*Increase in yield on the dieldrin plots over BHC plots (22 trials*)*
	Best BHC seed dressing (24 trials)	*Best dieldrin seed dressing (25 trials)*	
20·6 ± 2·18	8·0 ± 1·86	10·1 ± 1·68	0·71 ± 0·77

Note: * When a series of trials is designed to show significant treatment effects at the 5 per cent probability level, one in every 20 or so will give aberrant results. In the twenty-third trial in the present series the BHC plots gave 4·8 cwt. of grain less than the untreated plots, and the best dieldrin seed dressing gave 21·2 cwt. more than the BHC plots and 16·4 cwt. more than the controls. If the results of this trial are included in the BHC/dieldrin comparison (they have anyhow been included in the organomercury/dieldrin comparison) the dieldrin increase more-than-doubles:

1·6 ± 1·16 cwt. more grain than BHC.

These alternative values for dieldrin benefit (0·7 and 1·6 cwt.) are reflected in the appropriate column of the table at para. 1.7.

1.6.2. *Use of Seed Dressings against Cereal Wireworms.* Wireworms are widely distributed in old grassland, where high populations (over 1 million per acre estimated by wet extraction) are often found. Recent work at RES suggests that the critical population level at which control is worthwhile is about 250,000 per acre (wet extracted) for cereals. Most old grassland is likely to be infested at, or well above, this level and merits treatment if cereals are planted within two years of ploughing out. With temporary grassland the

available evidence indicates that it takes a good deal longer than 5–6 years for a residual "arable wireworm" population (of the order of 50,000 per acre) to build up to levels that can damage cereals.

SFP data show that:

$2\frac{1}{2}$ per cent of the cereal crop is drilled on ploughed-out old grassland;

and

1–$1\frac{1}{2}$ per cent follows old grassland in the second year after ploughing.

Wireworms sometimes do more damage in the second year after grass since in the first year they feed on the ploughed-in turf. It is thus suggested that at least $1\frac{1}{2}$ per cent (of 6,602,700 acres = approximately 100,000 acres) of the cereal crop merits annual wireworm treatment. However, to be completely safe it could be further argued that $1\frac{1}{2} + 2\frac{1}{2} = 4$ per cent of the crop merits treatment, and that as there are still a few areas (e.g., on the chalk, particularly in the Eastern and South-Eastern Counties) where "arable wireworm" is apparently a nuisance in some cereal crops it appears more realistic to take 6 per cent of the cereal acreage as meriting treatment: i.e., 400,000 acres.

In general, BHC seed dressings give a benefit of 4–$4\frac{1}{2}$ cwt. of grain per acre. If it is argued that this would be the loss over 400,000 acres if these seed dressings were no longer available, the average annual loss in England and Wales would be of the order of:

$(4{\cdot}2/30) \times 400{,}000 = 56{,}400$ equivalent acres per annum.

This assumes an average yield of 30 cwt. per acre in the absence of wireworms. It also implies that the use of dieldrin dressings in place of BHC would not materially alter the situation: there is no published evidence that dieldrin is more effective than BHC in this usage.

1.6.3. *Control of Leatherjackets.* NAAS trials in 1952 showed that DDT and BHC were satisfactory substitutes for paris green. Recent NAAS work on barley has shown that leatherjacket populations of the order of 250–500,000 per acre can reduce grain yield by about 5 cwt. per acre: and work on grass leys shows that the early bite can be doubled, and a good increase in hay yield obtained, if leatherjackets are controlled.

Leatherjackets tend to be localised: low-lying, poorly drained, grassland (temporary or permanent) in the Northern, East and West Midland, South-East and South-West Regions, and parts of Wales, tend to support high ($\frac{1}{2}$–1 million per acre) larval populations that are often worth controlling. While SFP data suggest that 30 per cent of the cereal crop follows first or second year ploughed-out leys and grassland it would be unrealistic to assume that anything like 30 per cent of the cereal acreage is At Risk from leatherjacket damage—even in an abnormally severe year.

1.6.4. *Wireworms in Maincrop Potatoes.* In 1962 the PMB Field Staff sampled 1,923 potato crops in the course of the annual Crop Check Survey. They found traces of wireworm damage in 56 of these crops; in 13 of them it was moderately heavy: at, or in excess of, $\frac{1}{2}$-ton of damaged tubers per acre out of an average total yield of over 9 tons per acre; on the other 43 crops the damage was of the order of 1–2 cwt. of specked tubers per acre. In the same year 456 of the 1,923 crops were treated with aldrinated fertiliser or aldrin spray for wireworm control.

In detail, the 1962 PMB Survey detected damage on 579 acres, and on 92 acres it was at, or above, the $\frac{1}{2}$-ton per acre level. At this level, aldrin treatment will reduce damage by almost exactly 50 per cent in the season of application. At lower levels of damage there is no detectable difference between treated and untreated crops. This is partly due to the difficulty of getting precise estimates at the 1 cwt. level with the sampling techniques in use. It is reasonable to suggest that, in 1962, only about 8 per cent of the wireworm loss could have been avoided by direct aldrin treatment: that is, 8 per cent of 1,630 acres = 130 Equivalent Acres (See para. 1.7.).

The evidenee on potato wireworm control suggests that aldrin treatments applied since 1954 have had a long-term effect on wireworm populations. It is doubtful whether aldrin is more than 50 to 75 per cent effeetive in the year of applicauion, and there is evidenee that a potato crop grown on wireworm-infested ground is likely to fail in the ware market whether it is given aldrin treatment or not.

The hest effects of aldrin treatment are seen a year or two after application, when repeated eultivations have given a good soil/inseeticide mixture. About 8 per eent of the potato crops in 1962 were grown on land that had been given at least its second aldrin treatment in that year. This usage is unneeessary for wireworm eontrol.

1.6.5. *Sugar Beet Soil Pests.* The inereasing use of preeision drills for sugar beet demands improved protection for seedlings sinee gapping in the stand cannot be made good. For example, in 1960–61, seedling populations averaged 140,000 per acre; within a few years it is antieipated that widesprcad use of rubbed seed will result in populations of about 100,000 per aere, while the steady increase in supplies of true genetical monogerm sced, whieh is sown to stand, give populations of 50,000 per aere or less. The workers at Broom's Barn Experimental Station have invcstigatied seed proteetion in detail. Thc results from 85 trials over the period 1956–60 showed a negligible benefit from dieldrin dressing on fields seleeted at random (an inerease in stand of 0·6 per eent). However, when trials were done on 36 sites known to suffer from soil pest damage dieldrin seed dressings gave a stand inerease of 6 per cent over the eontrols. BHC seed dressings gave an inerease of 4 per cent, the 2 per eent difference being duc partly to the phytotoxieity of existing BHC formulations.

The poliey deeision to dress all beet seed was made at a time when wireworm ineidenee appeared to be generally on the decline. The deeision was made beeause the offer of treated or untreated seed was seriously complieating its timely delivery to growers in the spring. Beet seed dressings are minimal in terms of aetive ingredient used per aere: approximately 0·5 ounce of BHC, and 0·6 ounce of dieldrin or heptachlor, per acre.

1.6.6. *Cabbage Root Fly.* Most of the experimental work on eabbage root fly has been done on eauliflowers and eabbages, with a few trials on turnips and sprouts. The trials done over the period 1951–57 at a range of sites show the following increases in marketable yield:

Cauliflowers: 2·7 times untreated yield;
Cabbagc: 2·3 times untreated yield; and
Turnips: 2·9 times untreated yield.
} Average Inerease: 2·5 times.

Root fly tends to be serious (taking half, or more, of the marketable yield) in dry years, and an extended series of observations at Cambridge in nine of the seasons between 1939 and 1951 showed a substantial yield-effeet in only five of the nine years. Later work at various centres has shown that up to 10–12 per eent of plants sueeumb to attaek even when dieldrin, BHC, or mercury ovieide, treatments are used.

The available information suggests the following yield increments per unit area:

'Perfeet Control' (not yet generally achieved):	2·75
Control by organochlorines:	2·50
Control using ealomel as an ovicide:	1·63
Untreated:	1·00

Recent work at thc NVRS indieates that diazinon (an organophosphorus eompound) is equal to the organochlorines in control effieiency except that it cannot be used as a dip. A large part of the eabhage crop is now dieldrin-dipped at transplanting, and if this operation were stopped about 21,400 acres of eabbages would be affected to some extent by root fly five years out of every ten. The alternative ealomel dip (whieh is still in use in a number of areas) would reeoup some of the potential root fly losses; and most eould probably be recovered by diazinon sprays, though these would add eonsiderably to the eost of the operation.

1.6.7. *Carrot Fly.* Between 1946 and 1950, before dieldrin was available, about $1\frac{1}{2}$ per cent of the early carrot crop was damaged by fly, and 3–23 (mean = 9) per cent of main-crop carrots were damaged. Subsequent work in 1948–1960 at many sites shows that on average:

0·5 per cent of roots are damaged following organochlorine treatment;

and

46·0 per cent of roots are damaged without treatment.

On celery in Yorkshire and Lancashire, the best BHC treatment gave a yield increase of 2·1 times over the untreated plots, and the best dieldrin treatment gave an increase of 2·0 times.

Carrot fly is widespread, and it is reasonable to accept that there is some return on treatment costs for maincrop varieties in most places and years. Recent work at the NVRS indicates that diazinon gives 90–98 per cent clean roots in the face of heavy carrot fly attacks. Dieldrin is inefficient to the extent that about 0·5 per cent of carrots are damaged by fly after treatment, and diazinon is inefficient to the extent that on average 4·0 per cent of roots are likely to be fly damaged following treatment. Diazinon has not yet been used on a commercial scale for carrot fly control in the U.K. In Holland, however, carrot fly is now widely resistant to heptachlor, aldrin, dieldrin and chlordane, and very good results have been obtained with diazinon.

1.6.8. *Mustard Seed Weevils.* DDT is unsatisfactory for the control of mustard seed weevils, and dieldrin is generally used for this purpose. Anything from 2 to 60 per cent of the pods on Trowse crops may be weevil infested (average for 26 crops in 1959 = 30 per cent), and seed yield can be reduced from 18 cwt. to 9–10 cwt. per acre in the absence of treatment. In 1958 the benefit from dieldrin sprays was nearer 2 than 9 cwt. compared with BHC at 1 cwt. and parathion at 1·7 cwt. per acre. In 1959, when attacks were heavier, dieldrin gave an increment of over 10 cwt. of seed per acre, compared with 4 cwt. from parathion and much the same from DDT.

1.7. *The Need for Aldrin and Dieldrin as Crop Pesticides.* In drawing together the information given in the preceding sections the convention of Acreage Equivalents has been adopted (para. 1.5.2.). For example, in the table below it is suggested that 18,100 acres

The Estimated Effectiveness of Aldrin/Dieldrin in the Field

Pests:	*Wheat bulb fly*	*Wireworm*		*Soil pests*	*Cabbage root fly*	*Carrot fly*	*Mustard weevil*
Crops:	*Winter wheat*	*Cereals (all)*	*Potatoes*	*Sugar beet*	*Edible brassicae*	*Carrots, celery*	*Trowse mustard*
Acreage grown . .	1,376,000	6,602,700	430,600	408,400	118,600	37,000	8,000
Maximum likely loss in the worst possible year	60,000	400,000	18,100	172,000	73,600	30,000	4,800
Possible *average annual loss* if areas "At Risk" remain untreated	30,000	56,400	1,600	10,300	25,900	17,000	2,400
Possible *average annual loss* if areas "At Risk" were treated *other than with aldrin, dieldrin, and heptachlor*	2,000–4,000	—*	?*	3,400	6,400	700	1,000
Possible *average annual loss* if aldrin, dieldrin and heptachlor continue to be used as recently	—*	—*	1,500	—*	2,600	200	—*

of maincrop potatoes are liable to wireworm attack. This figure was obtained by raising the total acreage of the 56 crops known to have been damaged in 1962 (para. 1.6.4.) in relation to the potato acreages in the counties concerned. Taking all 56 crops, and allowing for the usual increase in damage between the time of the PMB survey and the time the crops are lifted, it was found that 9 per cent of the tuber yield of 18,100 acres was actually damaged by wireworm, the balance of each crop usually being sound enough for the ware market after routine dressing out. Nine per cent of 18,100 = 1,630 acres = the Equivalent Acreage of tubers consigned to the stock-feed instead of the ware market. All of the estimates in the table have been obtained by similar lines of argument.

1.7.1. *Comments on Table Above.* The following points are relevant:

*Wheat Bulb Fly and Sugar Beet Soil Pests** It has been assumed that dieldrin and heptachlor are 100 per cent efficient and that no further gain could be obtained from alternative, as yet undeveloped, materials. Detailed work done by NAAS Entomologists in the Eastern Counties on the 1963 wheat crop indicates that none of the commercially established organochlorine wheat bulb fly treatments were 100 per cent efficient in that year.

*Cereal Wireworms** It has similarly been assumed that no further benefit can be obtained over that provided by BHC. The 400,000 acre loss is maximal in the sense that if exceptionally severe wireworm damage occurred on all crops At Risk, yields would be reduced from about 30 to about 5 cwt. per acre. At this level the crops would not be worth the cost of harvesting.

*Potato Wireworms** The only possible alternatives to aldrin are organophosphates which are still under investigation and their relative efficiency is not yet known. Note that the "current season" benefit from aldrin has been put at 100 acres of production.

Cabbage Root Fly. Generally it is only the cauliflower and cabbage crops that are affected by fly (paras. 1.3.4. and 1.6.6.). If consideration is restricted to these crops the relevant figures are:

Acreage grown: 45,000; Maximum likely loss: 36,000; Possible loss in absence of treatment: 16,000; Possible loss if aldrin and dieldrin not available: 4,000 (allowing for use of calomel and diazinon); Possible loss if aldrin and dieldrin continue to be used: 2,400 acres.

*Mustard Weevils** Dieldrin sprays assumed completely efficient.

1.8. *Main Conclusions on Aldrin and Dieldrin*

1.8.1. About 500,000 acres are treated annually with aldrin and/or dieldrin formulated as plant dips and seed dressings.

1.8.2. About 250,000 acres are treated annually with these materials formulated as fertiliser mixtures, dusts, sprays, and drenches ("spot treatments").

1.8.3. Effectively all these acres are planted with cereals, sugar beet, potatoes, edible brassicae, carrots, and Trowse mustard.

1.8.4. On the evidence available, dieldrin (and heptachlor) seed dressings save 2,000–4,000 acres of winter wheat per annum and a similar acreage of sugar beet. Possibly 4,000 acres of cabbages—at present root-dipped in dieldrin—would be badly damaged if this material was no longer available. Some 400–500 acres of strawberries are protected from seed beetle damage by aldrin; and aldrin materially improves narcissus production on 600–700 acres annually. Insufficient evidence is available to assess the average field value of the materials in relation to productivity of strawberries, narcissus, string beans, and onions, though it would seem that benefits to these crops, plus Trowse mustard, is unlikely to exceed 2,000–2,500 acres per annum.

PART 2: A NOTE ON CHLORDANE, ENDOSULFAN, ENDRIN, HEPTACHLOR, AND "RHOTHANE"

2.1. *Chlordane.* All reports indicate that chlordane is not used in agriculture in England and Wales. Its main use is as a turf pesticide for worm-killing, and packs are widely available to amateur gardeners and greenkeepers for this purpose. The material is believed to be in general use on sports turf, though the acreage treated annually is not known.

While it is undoubtedly an efficient worm-killer, chlordane is not essential for the maintenance of high class sports turf. There are alternatives (permanganate of potash, formaldehyde, lead arsenate, and derris), which, while not quite so efficient as chlordane, have given good results over many years.

2.2. *Endosulfan.* This is used on blackcurrants and strawberries and is widely used on the former crop against big bud mite. Surveys done in the Eastern Counties in 1961 and 1962 indicated that 80 per cent of the blackcurrant crop was sprayed at least once with endosulfan, and more than 60 per cent of the acreage was treated twice. In the West Midlands 80 per cent of the blackcurrant acreage was treated with endosulfan in 1963. Much of the national crop is grown in these areas and it is reasonable to take 80 per cent of the total crop as receiving treatment: about 12,300 acres per annum.

2.3. *Endrin.* This is used on apples and blackcurrants. Little is used on apples. Three seasons' work in the Eastern Counties indicated that about 10 per cent of the blackcurrant crop was sprayed with endrin. Usage is also known to be general in the South-East and South-West Advisory Regions.

Both endosulfan and endrin give good control of existing heavy bud mite infestations, but the present Recommendations under the Pesticides Safety Precautions Scheme do not permit the use of endrin at the post-blossom period when its action is most effective. Endosulfan may be applied post-blossom, but it is only about two-thirds as effective as endrin in dealing with heavy mite infestations.

It is not possible, at present, to state how far existing usage is justified on economic grounds. Recent work at Long Ashton Research Station indicates that excellent control of big bud mite can be obtained with three applications of 1 per cent lime sulphur each season. This has yet to be confirmed on a commercial scale, and it is likely that a general change-over would lead to phytotoxic losses in some varieties of blackcurrants. It seems clear that the two organochlorines are useful for eliminating existing heavy infestations, while lime sulphur may well be adequate to prevent subsequent re-infestation.

2.4. *Heptachlor.* Usage is restricted to cereal and sugar beet seed dressings. Surveys in the Eastern Counties indicate that approximately 13 per cent of the winter wheat in the susceptible areas of Cambridge, Huntingdon and Essex is drilled with heptachlor-dressed seed. Taking the East Midland Region as a whole, 10 per cent of the winter wheat acreage is thought to be so treated, while 15 per cent of the Lindsey acreage was drilled with heptachlor-dressed seed in 1962. In the West Midlands about 20 per cent of the winter wheat is dressed with dieldrin or heptachlor in years when there are high wheat bulb fly egg counts. The proportion dressed with each is unknown.

On the information at present available it seems that approximately:

56,000 acres of winter wheat receive heptachlor seed dressings, and

143,000 acres of sugar beet are drilled with dressed seed.

In so far as they both provide protection against wheat bulb fly and certain soil pests, there is little to choose between dieldrin and heptachlor seed dressings. The table at para. 1.7. indicates a possible average annual loss of 2,000–4,000 acres of winter wheat, and about 3,000 acres of sugar beet, if dieldrin and heptachlor seed dressings were no longer available.

2.5. *"Rhothane."* This material is used on apples, strawberries and some flower crops for the control of caterpillars, capsids, earwigs, thrips and beetles. Usage is believed to

be on a very small scale. Azinphos-methyl, (an organophosphate) gives better control of fruit caterpillars than "Rhothane."

Chemically, "Rhothane" is closely related to DDT, and it occurs in concentrations of up to 4 per cent in ordinary technical DDT. It has been found in detectable amounts in 4 out of 14 fields known to have been treated only with DDT. It seems that a significant —if not the major—part of the "Rhothane" story is included in the DDT usage data in Part 3 of this paper.

PART 3: USAGE OF DDT AND BHC

3.1. *Introduction.* DDT was first available in the U.K. for experimental use against crop pests in 1944–45. It was used commercially on fruit thereafter, but its use on field crops was limited until price reductions made treatment an economic proposition about three years later.

BHC was developed as an insecticide in England in 1942. Field trials were in progress in 1945–46. Because of the low cost of this material little time was lost in applying the results on a commercial scale: crude BHC wireworm and flea beetle dusts were freely available by 1947.

The comments hereunder therefore apply to increasing use on farm land over the past 15–16 years.

3.1.1. *Persistence.* DDT is at least as persistent as dieldrin in soil, and has a half-life of 2½–5 years. In practical terms, incorporation of 2 lb. of DDT into a loam soil (either directly, or as run-off or plough-in from treated plants) will give rise to a sorbed residue of approximately 1 lb. 2½–5 years later.

The soil half-life of BHC (gamma, and the other isomers), is less than that of DDT. Half of the applied dose usually disappears in a matter of 18 months, and after 4–5 years only about 10 per cent of the initial dose can be detected. Nevertheless, trouble still occasionally occurs from residues of crude BHC dust applied to the soil in the late 1940's for wireworm control.

3.1.2. *Methods of Application and Dosages.* DDT has limited uses as a soil insecticide, and is not formulated as seed dressings or with fertilisers for direct application in the U.K. BHC, because of its long-term tainting properties (even as the gamma-isomer), is not now applied directly to soil except in very small quantities as seed dressings. Dosages can be summarised as:

DDT and BHC Dosages (lb. active ingredient per acre) for Various Treatments

Material	*Sprays*	*Dusts*	*Seed dressings*
DDT . . .	0·4–2·0	2·8–5·6*	(not used)
BHC . . .	0·2–0·5	0·4–1·7	0·03–0·60

* DDT is applied at up to 15 lb. per acre in some leatherjacket control techniques.

3.2. *The Usage Estimates.* The sources of information noted at para. 1.2.1. also provided data on DDT and BHC usage. The estimates are of the same kind in both cases, and the reservations noted at para. 1.2.3. apply equally to DDT and BHC.

3.2.1. *Estimates of Acreage Treated.* The table below relates only to the major usages of DDT and BHC. Both materials are used against a wide range of pests, many of which are of sporadic importance. It is doubtful whether the acreage totals in the table would be materially altered if horticultural and amateur use were included.

The acreage estimates are of areas treated annually: the available evidence suggests that there are few fields in the main arable and orchard areas of England and Wales

which have not been treated at some time or other over the past 15–16 years with BHC and/or DDT. The estimates are not necessarily additive: many crops are seed-dressed against soil pests and also sprayed or dusted against foliage pests. In this respect it is not strictly correct to assume that the aldrin/dieldrin and DDT/BHC acreages are additive. Brassicae, for example, may be seed-dressed with BHC and subsequently sprayed with dieldrin; potatoes may be set on aldrinated fertiliser and later sprayed with DDT; and so on.

Acreages Grown, and Acreages Believed Treated, with DDT and BHC, England and Wales, 1962/63

Crop	Acreage grown, rounded to the nearest hundred	Acreage believed treated with DDT and BHC as:		
		DDT	BHC	
		Sprays and dusts	Sprays and dusts	Seed dressings
Wheat	1,834,300	29,700	12,900	608,200
Barley	4,153,400	10,000	118,700	1,082,900
Oats	615,100	7,800	3,800	249,800
Maincrop potatoes	430,600	14,800	2,100*	—
Sugar beet	408,400	4,500	1,600	61,300
Edible brassicae.	118,600	20,400	100	36,500
Stock-feed brassicae	392,300	—	—	216,900
Peas	118,700	24,600	—	—
Mustard	25,200	10,200	100	—
Soft fruit	35,300	13,600	—	—
Top fruit	186,900	119,600	58,000	—
Totals	8,318,800	255,200	197,300	2,255,600

* Given on some survey cards as "BHC wheat bulb fly dressing", and on others simply as "cereal seed dressing"; may include some leftover dieldrin and heptachlor dressings.
Soft fruit: Blackcurrants, strawberries and gooseberries.
Top fruit: Dessert and culinary apples, cherries, pears, gages and plums.

3.2.2. *The Areas Where Treatment is Applied*

*Estimated Area Usage of DDT and BHC in 1962/63: Acres Treated**

Crop	North	East	South	West
Wheat	66,700	439,600	98,800	45,700
Barley	207,700	577,500	333,000	93,400
Oats	47,200	154,600	18,500	41,100
Maincrop potatoes	—	16,100	—	800
Sugar beet	5,800	50,000	900	4,600
Edible brassicae	8,300	32,400	13,500	2,800
Stock-feed brassicae	27,200	36,300	95,400	58,000
Peas	1,700	22,800	100	—
Mustard	100	10,200	—	—
Soft fruit	(30)	12,200	800	600
Top fruit	600	113,400	26,200	37,400
Total acreage of qualified crops in each area	1,306,900	4,384,300	587,200	284,400

* Additivity has been assumed in preparing this table.

3.3. *The Pests for which Treatment is Applied.* DDT and BHC are in such general use against minor as well as major pests that an exhaustive list of the species is impracticable in the present context. Often, a control applied for one pest will affect another, and in the notes which follow the main emphasis is on those which the grower intends to control.

3.3.1. *Cereal Pests.* About 28 per cent of the wheat sown in the Eastern County wheat bulb fly areas is dressed with high concentration BHC seed dressing. The rest of the national wheat acreage, and the barley and oat acreages which receive DDT and BHC, are treated against wireworms, leatherjackets, occasionally cutworms, and frit fly. Wireworms are usually adequately dealt with by BHC seed dressings, and the major part of the dusted and sprayed acreage is treated against leatherjackets (para. 1.6.3.).

3.3.2. *Potato Aphids.* Many growers now save their own seed and apply organophosphorus sprays to at least part of their potato crops to try to control the aphid vectors of leaf roll and Y virus diseases. In addition, there is a group of growers—nearly all in the Eastern Counties—who include DDT in their routine blight sprays.

3.3.3. *Sugar Beet Pests.*

Soil Pests. The principal soil pest is "arable wireworm" which may cause gaps in precision-drilled crops. Millipedes are occasionally troublesome: in 1959 about 600 acres of beet were treated specifically for this pest, but normally separate treatment is not necessary. In most years 2–300 acres are treated against leatherjackets. See also para. 1.6.5. *Mangold fly* is sporadically important. In recent years an average of some 20,000 acres of beet have been treated annually for this pest. However, the use of organochlorines is actively discouraged by the BSC, and an organophosphate is now used on most of this acreage. In a bad mangold fly year, such as 1957, treatment may be applied to as much as 45,000 acres, and in the past DDT and BHC have been widely used for this purpose.

3.3.4. *Brassicae Pests.* Cabbage root fly has been dealt with at para. 1.3.4., and it remains to comment briefly on the other brassicae pests. The most important of these are a group of flea beetles, and something over half of the acreage of brassicae grown for stock feed is drilled with BHC-dressed seed which affords good protection. A smaller proportion of the edible brassicae is seed-dressed, largely because modern production methods involve planting out after the seedlings have passed the really susceptible stage. Drench treatments applied at transplanting for cabbage root fly control also affect flea beetles.

About 20,000 acres of edible brassicae are sprayed annually with DDT for a variety of pests: some is applied for flea beetle, some for cabbage caterpillars and occasionally some for diamond-back moth. Swede midge and turnip gall weevil also need treatment from time to time.

3.3.5. *Pea Pests.* Principally pea moth and *Sitona* weevils, though pea midge sometimes needs treatment in Lindsey and Yorkshire. In some years it is necessary to spray against pea aphid, leaf miners, and thrips in the Eastern Counties. In the main, however, it is moth and weevil that are most often sprayed. There appear to be two reasons: many vining contracts contain clauses about moth damage and growers are reluctant to risk the slightest damage. Much moth spraying is done as an insurance. Secondly, a surprising amount of weevil spraying is done. This may well be a grower's, as distinct from a processor's, decision because leaf notching looks serious even when effects on yield are small. In 1963, a year when nearly all Regional reports assessed weevil incidence and damage as light and below normal, one processor in the East Midlands has reported that 3,000 of his contract acres were treated with DDT against weevil, and a further 2,000 acres were treated with dieldrin. Detailed reports on 9,395 acres of peas treated in 1963 indicate that 70 per cent of the treatments were applied against weevil, 17 per cent against moth, and 13 per cent against aphid.

3.3.6. *Mustard Pests.* See para. 1.3.6.

3.3.7. *Soft Fruit Pests.* Principally strawberry seed beetle and root weevil; midge and capsid on blackcurrants; and gooseberry sawfly. Tortrix caterpillars are occasionally troublesome on soft fruit and are usually treated with DDT. Of the soft fruit not included in the table at para. 3.2.1., about 80 per cent of the Kentish raspberry crop is sprayed with DDT against raspberry beetle, and 10 per cent of the raspberry, blackberry, and

loganberry, acreages receive BHC for cane midge control. There are 2,670 acres of these crops grown in England and Wales, and 930 of them are in Kent.

3.3.8. *Top Fruit Pests.* Organochlorine insecticides are used on top fruit for controlling tortricid caterpillars, codling moth, winter moth, sawfly, and aphid. BHC is also used against plum sawfly. Treatments for caterpillar and aphid are usually applied at the pre-blossom stage (DDT) and may be followed by petal-fall sprays of BHC for sawfly control. It is important to appreciate that the DDT and BHC fruit acreages in the table at para. 3.2.1. are not additive: the two materials are often applied as a combined wash. Hence, the total top fruit acreage receiving these materials is much closer to 120,000 than 178,000.

Cider apples and perry pears have been excluded from the top fruit classification. Long Ashton Research Station workers argue that in recent years prices have been so low that neither crop can afford treatment. One other correspondent, however, suggests that 20 per cent of the West Midland cider apple acreage is sprayed pre-blossom with BHC/DDT wash. If this assessment is correct, the DDT and BHC top fruit totals should each be increased by 2,500 acres.

Fruit growers are tending to move away from the organochlorines in favour of carbamates and organophosphates. The higher cost of these chemicals is, however, an objection. Apart from this, the change-over might involve more critical timing of applications owing to reduced persistence of the spray deposits. It is, however, now possible to give more critically timed spray warnings than it was even five years ago, and it is also possible to state that alternatives to the organochlorines have been shown in field trials to be equally, if not more, efficient.

3.4. *Conclusions.* After allowing for joint usage on fruit, it appears that about 400,000 acres are treated annually with DDT and BHC sprays and dusts. About 2,250,000 acres are set with BHC-dressed seed.

From an overall viewpoint, DDT and BHC usage is greatest on cereals, brassicae and fruit, with sugar beet and peas receiving appreciable treatment in some, but by no means all, years. As in Part 1, an attempt has been made to estimate the degree to which this usage is justified, and the relevant arguments are summarised below.

3.5. *The Experimental Approach.* The general approach has been summarised at para. 1.5. The papers cited at para. 1.5.1. have also been used, where relevant, to provide data on DDT and BHC efficiency and many additional papers have been consulted.

3.5.1. *Sources of Information.* In addition to those cited at para. 1.5.1.:

Cereals: Finney: (*Ann. appl. Biol.*, **28**, 1941); Kring: (*Jour. Insect Pathology*, **4**, 1962); Bull. No. 128, Minist., Agr. Fish., 1944.

Potatoes: Broadbent, Burt and Heathcote: (Proc. 3rd. Conference on Potato Virus Diseases, Wageningen, 1957; *European Potato Journal*, **3**, 1960).

Brassicae: Miles, Finney and Anscombe: (*Agriculture*, **53**, 1946); Wright: (Rep. 13th Int. Hort. Congress, 1952); Williams and Carden; T. Glyn Davies; (*Plant Pathology*, **10**, 1961: **12**, 1963); Anon; Thomas; Rosborough: (*Plant Pathology*, **3**, 1954; **2**, 1953; 9, 1960).

Peas: Gould, Legowski and Atkins; Edwards: (*Plant Pathology*, **11**, 1962; **3**, 1954); Wright, Geering and Dunn; Dunn and Wright: (*Bull. Ent. Res.*, **41**, 1951; **46**, 1955); George Light and Gair; Bevan: (*Plant Pathology*, **11**, 1962; **10**, 1961); Dunn and Wright: (3rd Annual Report of the NVRS, 1952).

Soft Fruit: Ibbotson and Edwards: (*Ann. appl. Biol.*, **41**, 1954); Briggs: (Ann. Rep. EMRS for 1956 (1957)): Briggs and Tew: (*Bull. Ent. Res.*, **54**, 1963).

Top Fruit: Carden and Gould: (*Plant Pathology*, **11**, 1962); Dicker; Davies and Eaton; Joan R. Groves; Dicker and Briggs; Groves and Tew; Barlow, Dicker and Briggs; Tew and Groves; Chiswell: (Ann. Reps. EMRS for 1949, 1951, 1952, 1954, 1955, and 1962); Chiswell: (*J. Hort. Sci.*, **37**, 1962).

3.5.2. *Procedure.* As set out for aldrin/dieldrin at para. 1.5.2.

3.6. *Summary of Experimental Estimates of Yield Increases from Use of DDT and BHC.* In each of the cases set out below a detailed argument has been prepared and only a brief summary is given here.

3.6.1. *Use of Seed Dressings against Cereal Wireworms.* The main argument has already been given at para. 1.6.1. Two points remain: first, the benefit to be gained from plain organomercury dressings. Country-wide trials done by NAAS entomologists in 1949 indicated that seed treated with an organomercury dressing gave 1·8 cwt. per acre more than undressed seed. This compared with an increase of 4·2 cwt. from a BHC/mercury dressing. There was a lower level of plant damage on the organomercurial plots, indicating that the yield increase was a wireworm, rather than a fungicidal, effect. Secondly, recent changes in farming practice, particularly the widespread adoption of ley farming, appear to have reduced wireworm populations in general.

3.6.2. *Sugar Beet Pests.* The argument in respect of soil pests is given at para. 1.6.5. With regard to mangold fly, records extending back to 1917 show that the fly was "serious" in only 12 of the 46 years or 1 year in 4. Essentially, the fly is only a nuisance in seasons when there is poor, backward, growth at the time of singling. Trials done in such years show that fly control gives an average yield increment of about 5 per cent. An organophosphate is now recommended in these conditions.

3.6.3. *Potato Aphids.* In the period 1940–1960 there were only three springs when potato aphids were numerous early in the season. Data from 34 trials done over the period 1952–1958 indicated that the incidence of leaf roll virus could be halved by controlling the aphid vectors. In approximately 1 year in 7 the aphids are sufficiently numerous to do damage in their own right, and experimental yield increases of the order of 6 per cent have been obtained. However, when treatments are applied by tractor-mounted sprayer on a field scale there is a measurable loss due to damage to the plants by the tractor wheels. Put at 5–6 per cent this loss just balances the non-virological benefit gained from aphid control.

3.6.4. *Pea Moth and Weevil.* It is unusual for moth to damage more than about 6 per cent of the peas in early-drilled crops, and up to about 20 per cent may be damaged in late crops, of green peas. Damage to late-harvested, dry, peas can be four times as bad as on otherwise comparable green crops. Sprays as used at present do not seem to be very efficient: 193 crops of dried peas were inspected over a three year period, and the average loss of peas on those crops that had been sprayed was 6 per cent, compared with 9 per cent on the untreated crops. Field trials have generally given a 50 per cent reduction in pod attack, and the latest information (1963) indicates that several organophosphates are as good as DDT in moth control. Nowadays only about 23,000 acres of the national crop of 120,000 acres are set to dried peas; and two-thirds of the green crop is set early and substantially escapes moth and aphid damage.

With weevil, a series of trials failed to detect any yield effects as a result of nodule damage, whether the plants were growing on good soil or bad. Leaf damage by weevil must be severe to have any effect on yield at all: 10–12 per cent of the total leaf area must be destroyed at the 'four expanded leaflet' stage in order to produce a small yield loss. Damage to this extent at this time is rare in the field.

3.6.5. *Brassicae Pests.* An account of damage caused by cabbage root fly has already been given at para. 1.6.6. In 1963, which was a bad root fly year in the Eastern Counties, there was a reduction in size, but not in number of marketable heads in untreated crops. Nowadays large heads are not often wanted. It remains to emphasise that calomel, used as an ovicide at transplanting time gave an average increase in yield of 63 per cent in six years when appreciable fly attack took place. The average increase from use of organochlorines is twice this, while foliage sprays of diazinon are about equal in efficiency to the organochlorine compounds.

Flea beetles are the only serious pest of stock-feed brassicae and, in a bad year, 10–15 per cent of the acreage may have to be re-drilled if seed dressings are not used. Before DDT and BHC were available derris was sometimes used for flea beetle control. Comparative trials indicated that derris gives a yield increase of about 15 per cent, compared with about 20 per cent from DDT dust. Later work has shown that DDT sprays give an even better control.

3.6.6. *Mustard Beetles.* On average, treatment appears to give an increase in seed yield of about 30 per cent; but in the face of heavy attacks by both pollen beetles and seed weevils it may be doubled. Damage is most severe on late-sown crops, and yield increases of 10 per cent or less may be maximal for early sown crops. See also para. 1.6.8.

3.6.7. *Top Fruit Caterpillars.* Field trials in which yields were obtained have been done at East Malling over the past 10 years. The data—including some recent unpublished work—have been pooled and are presented below as overall averages:

Percentage of Fruit Damaged at Harvest

Treatment	*By sawfly*	*By tortricids*	*By codling moth*
BHC and/or DDT	0·5	6·0	0·5
Organophosphates	0·5	2·0	0·5
Untreated	13·0	22·2	9·5

In the last five years improvements in spray timing, and in the efficiency of application, have given greatly improved control. It is no longer realistic to assume that data published in the early 1950's reflect the present-day position; in the meanwhile codling moth appears to have decreased in importance: a recent inspection of 700 acres of Kentish apple orchards at the optimum time revealed only 2 codling moths.

Fruit tree tortrix and summer fruit tortrix are both included under "Tortricids". In both cases damage is very localised, and the best available estimates indicate that each species is sporadically important on about 10 per cent of the apple acreage; but the localities are not completely identical, and for the present purpose they are taken as independent. Thus the damage by all caterpillars is additive:

Sawfly: 13 per cent of 124,000 acres = 16,100 acres,
Tortricids: 22 per cent of 20 per cent of 124,000 acres = 5,500 acres
Codling: 9·5 per cent of 124,000 acres = 11,800 acres

These figures suggest an estimated 33,400 acre possible average annual loss. This estimate does not include winter moth, for which there are insufficient data.

There is little information on the yielding efficiency of treatments against other fruit pests. An exception is plum sawfly: eight trials done in the Eastern Counties during the period 1950–1960 indicated that carbaryl, a carbamate, reduced damage from an average of 23 per cent spoiled fruit to 6 per cent. Gamma-BHC was little better than the untreated controls.

EMRS workers have recently summarised the position with regard to fruit pest control. Azinphos-methyl ("Gusathion") is now generally recommended in place of the organochlorines, and concurrent control of tortrix and codling can be obtained provided the timing is optimal. For winter moth it is possible that carbaryl could replace DDT, but no results of tests in the U.K. are available as yet. With regard to aphids, alternatives to the organochlorines are all more effective and demand less critical timings to give satisfactory control. With soil pests, however, no satisfactory alternatives are available for use against wireworms and wingless weevil grubs on soft fruit.

This completes the list of pests for which fair efficiency analyses can be made in respect of DDT and BHC usage. It remains to summarise the results in comparable area terms.

3.7. *The Need for DDT and BHC as Crop Insecticides.* Acreage Equivalents have again been used to express the results in uniform terms (para. 1.7.). It will also be noted that some of the entries in the table below are shown also in table 1.7. This has been done because the alternatives to aldrin/dieldrin treatment are mainly treatments with other organochlorines: for example, 4,000 equivalent acres of winter wheat might be lost in a bad wheat bulb fly year if dieldrin seed dressings were no longer available and the acreage At Risk was treated with BHC instead. At this stage in the argument it is unrealistic to consider the various materials in separate, watertight, compartments. The table below therefore relates to all the relevant organochlorine compounds.

Estimated Effectiveness of Organochlorines in the Field

Crop (1)	Pests (2)	*Maximum likely loss* (3)	*Possible average loss* (4)	*Possible average annual loss if organochlorines continue to be used as at present* (5)	*Possible average annual loss if organochlorines are not used at all* (6)
Winter wheat	Fly	60,000	30,000	—	30,000
All cereals	Wireworm	400,000	56,400	—	32,400
Sugar beet	Wireworm	172,000	10,300	—	10,300
Sugar beet	Mangold fly	20,400	5,100	—	—
Potatoes	Wireworm	18,100	1,600	1,500	1,600
Potatoes	Aphids	25,800	3,700	—	—
Peas	Moth, weevil	20,500	4,200	2,100	4,200
Brassicae:					
Edible	Root fly	73,600	25,900	2,600	6,400
Stock	Beetles	80,800	58,800	—	22,000
Mustard	Beetles	8,000	3,300	—	2,000
Carrots, celery	Fly	30,000	17,000	200	700
Apples	Caterpillars	86,500	33,400	1,000	1,000
Totals		995,700	249,700	7,400	110,600

3.7.1. *Comments on Table at* 3.7. The crops noted in the table cover an annual acreage of 8,257,000. The maximum loss likely from the pests named is equivalent to the production from almost exactly 1 million acres. Concurrent losses on this scale in any one year in England and Wales have not been recorded in the present century, and it would be an event of unique entomological interest if such a wide range of diverse pests were to flare up at one and the same time. A more realistic estimate is provided by column (4), which suggests that about 250,000 acres of production might be lost annually if no control measures were taken to combat the named pests.

The fifth column in the table represents the production lost at present through field inefficiency of the organochlorines. It will be noted that seven of the items are zeros, implying that organochlorines are completely efficient in these usages. This is not strictly true, and the zeros really indicate that no more efficient substitute has yet been discovered, or, of course, that the spray methods rather than the biological activity of the chemicals are at fault.

Column (6) sums to approximately 111,000 acres, and indicates the order of loss which might have to be faced for a few years if all organochlorines were withdrawn. It will be appreciated that such a loss would probably only be temporary: organophosphate, carbamate, and other chemical and biological substitutes would probably be found quite quickly; indeed, much experimental work has already been done along these lines.

3.8. *Overall Summary of Organochlorine Insecticide Usage.*

3.8.1. *Total Usage.* Pooling all the usage data in Parts 1, 2, and 3 gives the following results:

First Approximation to Total Organochlorine Usage, 1962/63

Material	*Acreage treated annually with:*	
	Sprays and dusts, etc.	*Dips and seed dressings*
Aldrin and dieldrin	259,950	453,200
Endrin and endosulfan	22,800	—
Heptachlor	—	199,000
BHC	197,300	2,255,600
DDT	255,200	—
Grand Total.	735,250	2,907,800

It appears that about ¾-million acres are treated annually with sprays, dusts, and fertiliser mixes, and nearly 3 million acres are drilled with dressed seed or set with dipped plants. These estimates may be slightly exaggerated because additivity has been assumed in arriving at them.

3.8.2. *Justification for Organochlorine Insecticide Usage in relation to Alternative Materials.* Leaving aside the point that about 3¾-million acres are treated annually to recover pest losses of about ¼-million crop production acres, it is worth seeing how far the extended use of known alternatives might modify the need to use organochlorines. This has been done in respect of the pests in the table at para. 3.7., and the result is shown below.

Annual Acreage of Qualified Crops: 8,257,000 acres.

Estimated Average Potential Pest Loss: 249,700 equivalent acres.

1. *Estimated Loss Preventable by Increased Use of Existing Alternatives.*

Crop	Materials	Acreage	
Carrots	Diazinon	16,300	
Cereals	Organomercury dressings	24,000	
Sugar beet	Dimethoate, demeton-methyl	5,100	
Potatoes	Menazon, dimethoate	3,700	
Brassicae	Diazinon, calomel, derris	56,300	
Mustard	Parathion	1,300	
Apples	Azinphos-methyl, carbaryl	32,400	
			139,100

2. *Estimated Loss Economically Preventable by Established Use of Aldrin, Dieldrin and Heptachlor.*

Winter wheat	Dieldrin and heptachlor	30,000	
Sugar beet	Dieldrin and heptachlor	3,400	
Brassicae	Aldrin and dieldrin	3,800	
Mustard	Dieldrin	1,000	
Carrots	Dieldrin	500	
Potatoes	Aldrin	100	
			38,800

3. *Estimated Loss Economically Preventable Only by Established Use of DDT/BHC.*

Crop	Materials	Acreage	
Cereals	BHC seed dressings	32,400	
Sugar beet	BHC seed dressings	6,900	
Brassicae	DDT and BHC	22,000	
Peas	DDT	2,100	
Mustard	DDT	1,000	
			64,400

4. *Estimated Irrecoverable Loss due to Inefficient Practice*

	Column (5) of table at para. 3.7.	7,400
	Total	249,700

These figures suggest that the real benefit from use of the organochlorines is of the order (38,800 + 64,400) = 103,200 equivalent acres per annum. In practice the benefit is rather greater: calomel is only used for cabbage root fly control in a few areas nowadays, and diazinon, though widely used on the Continent, is not yet available to U.K. cabbage and carrot growers. Summing all cases where the organochlorines are used, even though alternatives are already available, the credit balance becomes:

Aldrin, dieldrin and heptachlor:	80,000 acres
DDT and BHC:	120,400 acres
Total:	200,400 acres

This paper covers only part of the crop pest situation. This is because there is a lack of information on realistic pest and yield relationships for the other pests against which the organochlorines are used. These include:

Leatherjackets on cereals and temporary grassland;
Aphids on peas, and soft and top fruit;
Sawfly, beetles, midge and caterpillars on soft fruit;

There are also some species which are occasionally of local importance, e.g.; large narcissus bulb fly; bean seed fly; and onion fly.

Any attempt to estimate the benefit from controlling these pests must entail a large element of speculation. Taking the little evidence that is available, the following answers are obtained:

Leatherjackets: Say 5 cwt. of grain per acre on 2 per cent of the cereal acreage in the Northern, Yorks. and Lancs., and East and West Midland Regions, and 5 per cent in the South-East (Reading) and South-West (Bristol and Starcross) Regions one year in three:

$1/3 \times 5/30 \times 147{,}000$ = about 8,200 acres or, in a really bad year, about 25,000 acres.

Leatherjackets are readily controlled with DDT, BHC, and dieldrin.

Narcissus fly: Say 30 per cent attack on 700 acres of untreated bulbs, compared with 0·1–2·0 per cent attack on aldrin or dieldrin-dipped bulbs:

About 200 acres lost in absence of treatment.

Strawberry ground beetles: Say 15 per cent of damaged fruit in Kent, compared with 1–2 per cent following aldrin/dieldrin treatment:

About 500 acres lost without treatment.

These three examples, which are based on field experiments, suggest that damage by the pests which it has been impossible to analyse in detail can be reckoned in thousands, rather than tens of thousands, of equivalent acres per annum. Couple this with the fact that aphids are now more efficiently treated with organophosphates than organochlorines, and it seems reasonable to put the overall annual benefits from the main organochlorines at approximately:

Aldrin, dieldrin and heptachlor:	100,000 acres
DDT and BHC:	150,000 acres
Total:	250,000 acres

These benefits relate to acreages treated, or set with dressed seed or dipped plants, of:

Aldrin, dieldrin and heptachlor:	912,150
DDT and BHC:	2,708,100
Total:	3,620,250

These data suggest that the present usage of organochlorines is excessive in terms of resulting benefits. However, the patchy nature of pest damage requires that whole fields, rather than parts thereof, be treated if control operations are to be done economically. There is also an undoubtedly strong impulse for growers who have once suffered noticeable pest damage to make routine applications as a crop insurance. A number of cases have been noted in this paper (e.g., potato wireworms; sugar beet soil pests; cereal wireworm) where annual treatments appear to be greatly in excess of real need.

3.9. *Main Conclusions on DDT and BHC*

3.9.1. About 250,000 acres are treated annually with DDT sprays and dusts.

3.9.2. About 200,000 acres are similarly treated with BHC sprays and dusts.

3.9.3. About 2,250,000 acres are drilled annually with BHC-dressed seed.

3.9.4. The major part of these acreages is planted with cereals, sugar beet, brassicae, and top fruit.

3.9.5. The practical benefits from this usage can be put at about 150,000 crop production acres per annum.

GENERAL CONCLUSIONS

1. If chlordane, endrin, endosulfan, heptachlor, and "Rhothane" were to be withdrawn from use the total of agricultural production would be little affected. Heptachlor seed dressings would be replaced by dieldrin dressings for cereals and sugar beet. Some soft fruit growers would have to change from endrin/endosulfan to lime sulphur and other materials for gall mite control pending development of better substitutes. There may be some loss of efficiency here and annual costs might increase slightly.

2. If aldrin and dieldrin were to be withdrawn as well as the materials mentioned in (1) above, there would be an annual loss of about 4,000 acres of winter wheat, and similar losses to cabbages and sugar beet. Some bulb, soft fruit, and vegetable growers might be affected to a certain extent. These losses would probably be temporary. There would also be damage to about 17,000 equivalent acres of carrots, most of which could probably be made good by use of diazinon right away. The cost would, however, be greater than with continued use of dieldrin.

3. If all organochlorine insecticides were withdrawn, there would be an annual potential loss of about 250,000 acres of crop production. About 100,000 acres could be made good immediately by changing to alternative materials which are already available.

Possibly a further 75,000 acres could be made good within a short time by extended use of materials which are at present more expensive than aldrin, dieldrin, DDT and BHC (for example, menazon, disulfoton, azinphos-methyl, phorate). The final 75,000 equivalent acres might present more difficult problems (e.g. the development of reasonably persistent, non-phytotoxic, organophosphates which are of low enough vertebrate toxicity to be used as soil pesticides without wild-life hazards). This loss would fall heavily on cereal, sugar beet, and brassicae growers, though a range of high-value horticultural and vegetable crops would also be affected.

Note: These conclusions have been reached by the writer on the evidence available to him up to 31st December, 1963.

Plant Pathology Laboratory,
Harpenden.

APPENDIX F

Organochlorine Pesticide Residues in Foods

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Pesticide	*Food*	*No. of samples*	*Range of pesticide residues in parts per million*	*Mean residue‡ (arithmetic) in parts per million*	*Consumption of foodstuff g/head/day (1962 N.F.S.)**	*Consumption of pesticide mg/head/day from average consumption of foodstuff containing mean residue†*
Dieldrin (dieldrin	*Butter*					
	(Home produced)	15	0·04–0·20	0·07	25·1	0·0018
	(Australia) .	12	0·00–0·05	0·01		0·00025
aldrin for	(New Zealand) .	30	0·00–0·20	0·025		0·0006
potatoes)	(Denmark) .	20	0·00–0·20	0·035		0·0009
	Milk . .	50	0·00–0·005	0·003	418·9	0·0013
	Mutton kidney fat					
	(Home produced)	61	0·00–10·0	2·4§	6·1	0·015
	(Australia) .	10	<0·03–0·1	0·03	(Mutton and	0·00018
	(New Zealand) .	9	<0·03–0·1	0·03	lamb fat)	0·00018
	(Argentine) .	33	<0·03–6·0	0·05		0·0003
	Beef kidney fat					
	(Argentine) .	10	<0·1–0·8	0·1	6·7 (Beef and veal fat)	0·00067
	Corned beef					
	(Argentine) .	4	0·00–0·25	0·1	2·6	0·00026
	Potatoes . .	52	0·00–0·09	0·015	217·1	0·0033
DDT/DDE	*Butter*					
	(Home produced)	15	0·00–0·08	0·03	25·1	0·00075
	(Australia) .	12	0·00–0·8	0·28		0·007
	(New Zealand) .	30	0·00–1·2	0·26		0·0065
	(Denmark) .	20	0·00–0·02	0·001		0·00002
	Milk . .	50	0·00–0·01	0·0035	418·9	0·0015
	Potatoes . .	52	0·00–0·062	0·0025	217·1	0·00054
BHC	*Butter*					
	(Home produced)	15	0·00–0·24	<0·09	25·1	<0·0023
	(Australia) .	12	0·00–0·04	0·007		0·0002
	(New Zealand) .	30	0·00–0·02	0·004		0·0001
	(Denmark) .	20	0·00–0·04	0·02		0·0005
	Milk . .	50	0·00–0·01	0·003	418·9	0·0013
	Mutton kidney fat					
	(Home produced)	61	0·00–4·7	0·54	6·1 (Mutton and lamb fat)	0·0033
	Beef kidney fat					
	(Argentine) .	12	0·00–0·15	0·08	6·7 (Beef and veal fat)	0·00054
	Corned beef					
	(Argentine) .	4	0·00–0·25	0·15	2·6	0·00039
	Potatoes . .	52	0·001–0·019	0·008	217·1	0·0017

* 1962 National Food Survey.
† Calculated from columns (5) and (6).
‡ The arithmetic mean has been used for simplicity, in view of the limited number of results so far available. With the exception of the arithmetic mean value for dieldrin in home-produced mutton kidney fat (2·4 p.p.m.), these mean values do not differ significantly from median values (1·7 p.p.m. in the instance quoted).
§ But see paragraph 63 of the Report.

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REVIEW
of the
PERSISTENT
ORGANOCHLORINE
PESTICIDES

REPORT BY THE ADVISORY COMMITTEE
ON POISONOUS SUBSTANCES USED IN AGRICULTURE
AND FOOD STORAGE

to the Minister of Agriculture, Fisheries and Food,
the Minister of Health
and the Secretary of State for Scotland

FEBRUARY 1964

LONDON
HER MAJESTY'S STATIONERY OFFICE
1964

CONTENTS

Chapter		Paragraph
	Preface	(Opposite)
I.	Introduction	1–11
II.	The Uses of the Persistent Organochlorine Pesticides:	12–13
	(a) in agriculture, horticulture and home gardens	14–26
	(b) in food storage practice, industrial premises and the home	27–43
	(c) in veterinary practice	44–58
III.	Residues in Food	59–68
IV.	The Hazards to Man	69–82
V.	The Hazards to Wild Life	83–107
VI.	The Problem of Insect Resistance, particularly in relation to Persistent Organochlorine Pesticides	108–116
VII.	Discussion	117–128
VIII.	Conclusions	129–145
IX.	Recommendations	146–148
X.	Acknowledgments	149–150

Appendix		Page
A.	Part I— Membership of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage	31–32
	Part II— Membership of the Scientific Subcommittee	33
	Part III—Membership of the Veterinary Subcommittee	34
B.	Organisations and Individuals who submitted Evidence	35
C.	Persistent Organochlorine Pesticides and their Principal Metabolites of Interest	36–40
D.	Uses of Organochlorine Pesticides against Specified Pests:	
	Part I —Agricultural and Horticultural Uses	41–43
	Part II—"Approved" Home Garden Uses	44
E.	Persistent Organochlorine Pesticide Usage on Crops in England and Wales	45–67
F.	Organochlorine Pesticide Residues in Foods	68

PREFACE

A brief description is given below of the three Government schemes in existence which deal with the use of pesticides in agriculture and food storage, and of the Agriculture (Poisonous Substances) Act, 1952.

(a) *Pesticides Safety Precautions Scheme* (formerly known as the Notification of Pesticides Scheme).

This is a voluntary Scheme, agreed between the associations representing the pesticide manufacturers and the Agriculture and Health Departments in Great Britain, whereby manufacturers have undertaken to notify the Ministry of Agriculture, Fisheries and Food before marketing new chemicals or recommending a new use of an existing chemical. Manufacturers have to provide extensive data which include details of the physical, chemical and biological properties of the chemical compound, its persistence, the products into which it may break down, and its mode of action. Details of experimental work on its toxicity to mammals and (where available) to man are called for, as well as information on its likely effects on wild life, including birds, bees and fish. Methods of analysis, medical data, and any particulars of its uses in other countries are also required.

These data and all other available information are considered by the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage, and its Scientific Subcommittee. Provided it is satisfied that adequate practicable safeguards can be applied to protect the user of the chemical, the consumer of the treated crops, and wild life generally, the Advisory Committee makes recommendations for the safe use of the chemical which, if accepted by the Government Departments concerned, are published and widely distributed. It is a condition of clearance that the manufacturers must include the recommended precautions and restrictions on the label of the product. If the Committee is not satisfied that the tests and trials were adequate, it can require the manufacturers to carry out further experimental work. The Advisory Committee and Departments also have power to review the safe use of any chemical at any time, in the light of new evidence.

(b) *Veterinary Products Safety Precautions Scheme*

This Scheme, which was recently introduced after consultation with the professional and commercial organisations concerned, is designed initially to cover those veterinary products on sale direct to farmers. It will operate, in respect of those products, broadly on the lines of the Pesticides Safety Precautions Scheme. The Advisory Committee on Poisonous Substances receives scientific advice about these products from a Veterinary Subcommittee.

(c) *Agricultural Chemicals Approval Scheme*

This is a voluntary Scheme under which proprietary brands of crop protection chemicals (insecticides, fungicides and herbicides) can be submitted for official "approval" of their biological efficiency. The purpose of the Scheme is to enable users to select, and advisers to recommend, efficient and appropriate crop protection chemicals for use against particular pests and to

discourage the use of unsatisfactory products. The Scheme covers only those chemicals used for the control of plant pests and diseases, for the destruction of weeds, for growth regulation, and other crop protection purposes. It does not cover rodenticides, or pesticides used for food storage, veterinary or domestic purposes.

The Scheme is operated by the Agricultural Chemicals Approval Organisation on behalf of the Agricultural Departments of the United Kingdom. "Approval" is granted by the Organisation for specific uses, under United Kingdom conditions, only when the Organisation is satisfied that the product fulfils the claims made on the label, and these are subject to constant review.

The Scheme does not deal directly with the operator and consumer safety requirements, but "approval" of the efficiency of a product containing a new chemical cannot be given until it has first been considered and cleared for safety under the Pesticides Safety Precautions Scheme. "Approved" products (as distinct from those cleared only for safety under the Pesticides Safety Precautions Scheme) bear the "A" symbol on the label. A "List of Approved Products for Farmers and Growers" is issued annually.

(*d*) *Agriculture* (*Poisonous Substances*) *Act*, 1952

This Act is designed to protect agricultural workers by ensuring that they are supplied with, and use, protective clothing when working with the more toxic pesticides, i.e. those included in Regulations made under the Act. These "regulated" pesticides are listed in the Second Schedule to the Agriculture (Poisonous Substances) Regulations, 1963; the First Schedule shows the types of protective clothing required when particular operations are carried out. Pesticides are added to these Regulations from time to time, on the advice of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage.